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Report No. CG-D-20-90

(2)

AD-A230 638

**Q-ROUTE SURVEY DEMONSTRATION PROJECT
OPERATIONAL ASSESSMENT**

**Lee Alexander
Richard T. Walker
Scott L. Krammes**

**U.S. Coast Guard
Research and Development Center
Avery Point
Groton, CT 06340-6096**



**FINAL REPORT
JUNE 1990**

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National Technical Information Service, Springfield, Virginia 22161

Prepared for:

**U.S. Department Of Transportation
United States Coast Guard
Office of Engineering, Logistics, and Development
Washington, DC 20593-0001**

91 2 04 081

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**SAMUEL F. POWEL, III
Technical Director
U.S. Coast Guard Research and Development Center
Avery Point, Groton, Connecticut 06340-6096**



Technical Report Documentation Page

1. Report No. CG-D-20-90	2. Government Accession No.	3. Recipient's Catalog No.	
4. Title and Subtitle Q-ROUTE SURVEY DEMONSTRATION PROJECT OPERATIONAL ASSESSMENT		5. Report Date JUNE 1990	
		6. Performing Organization Code	
7. Author(s) Lee Alexander, Richard T. Walker, Scott L. Kramines		8. Performing Organization Report No. R&DC 15/90	
9. Performing Organization Name and Address U.S. Coast Guard Research and Development Center Avery Point Groton, Connecticut 06340-6096		10. Work Unit No. (TRAIS)	
		11. Contract or Grant No.	
12. Sponsoring Agency Name and Address Department of Transportation U.S. Coast Guard Office of Engineering, Logistics, and Development Washington, D.C. 20593-0001		13. Type of Report and Period Covered FINAL REPORT	
		14. Sponsoring Agency Code	
15. Supplementary Notes			
16. Abstract <p>This report presents the results of a joint U.S. Coast Guard (USCG) - U.S. Navy (USN) Q-Route Survey project conducted in New London, CT. USCG vessels were equipped with commercially-available equipment and systems, and manned by a mix of USCG and USN personnel. The results of at-sea operational evaluations intended to measure the effectiveness of an integrated navigation/data management system in meeting Q-route survey mission requirements are discussed.</p> <p>An integrated system configuration comprised of side scan sonar, display/data management, and navigation/positioning sub-systems was found to be highly effective for conducting detailed Q-route surveys. USCG vessels, including a 55' ANB and a 65' WYTL, are suitable platforms from which to conduct coastal Q-route survey operations. There were no significant vessel-related constraints associated with available working space, minimum vessel speed, or electrical power. All equipment could be installed in one working day. A joint-service approach to Q-route survey operations effectively utilizes existing skills and talent. With only minimum training/instruction, assigned USN personnel operated the equipment consoles while USCG personnel piloted the vessel and deployed/recovered the side scan sonar and acoustic tracker hydrophone.</p> <p>The most critical factor impacting the effective conduct of route survey operations was the availability and performance of the radio navigation system. During these trials Differential Loran-C provided a predictable, geodetic accuracy of 23 meters, 2 DRMS. The published tactics and procedures on the conduct of Q-route survey operations when using side scan sonar are not well defined. Further controlled testing and validation is needed to determine the probability of detection and effective search width for ocean floor objects and features.</p> <p><i>Keywords: LORAN, Coast Guard ships, integrated surface navigation, Data management</i></p>			
17. Key Words Q-route Survey Side Scan Sonar Integrated Navigation/ Data Management System Operational Assessment 65' WYTL 55' ANB Acoustic Positioning System Differential Loran-C		18. Distribution Statement Document is available to the U.S. public through the National Technical Information Service, Springfield, Virginia 22161 <i>unclassified</i>	
19. Security Classif. (of this report) UNCLASSIFIED	20. SECURITY CLASSIF. (of this page) UNCLASSIFIED	21. No. of Pages	22. Price

Form DOT F 1700.7 (8/72) Reproduction of form and completed page is authorized

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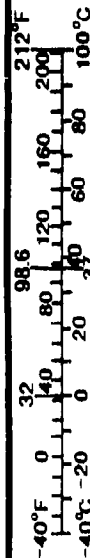
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
in	inches	* 2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
AREA				
in ²	square inches	6.5	square centimeters	cm ²
ft ²	square feet	0.09	square meters	m ²
yd ²	square yards	0.8	square meters	m ²
mi ²	square miles	2.6	square kilometers	km ²
	acres	0.4	hectares	ha
MASS (WEIGHT)				
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
VOLUME				
tsp	teaspoons	5	milliliters	ml
tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft ³	cubic feet	0.03	cubic meters	m ³
yd ³	cubic yards	0.76	cubic meters	m ³
TEMPERATURE (EXACT)				
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

* 1 in = 2.54 (exactly)

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply By	To Find	Symbol
LENGTH				
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
AREA				
cm ²	square centimeters	0.16	square inches	in ²
m ²	square meters	1.2	square yards	yd ²
km ²	square kilometers	0.4	square miles	mi ²
ha	hectares (10,000 m ²)	2.5	acres	
MASS (WEIGHT)				
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
VOLUME				
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	0.125	cups	c
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m ³	cubic meters	35	cubic feet	ft ³
m ³	cubic meters	1.3	cubic yards	yd ³
TEMPERATURE (EXACT)				
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



ABBREVIATIONS/ACRONYMS

ANB	Aids to Navigation Boat (USCG)
ASF	Additional Secondary Factor
ASW	Anti-Submarine Warfare
COMARDEZSECONE	Commander, Maritime Defense Zone Sector One, Boston
COMINEWARCOM	Commander, Mine Warfare Command
COMUSMARDEZLANT	Commander, Maritime Defense Zone Atlantic
COOP	Craft of Opportunity Program
DGPS	Differential Global Positioning System
DLC	Differential Loran-C
DRMS	Distance Root Mean Square
GPS	Global Positioning System
GRI	Group Repetition Interval
INS	Integrated Navigation System
IRSS	Integrated Route Survey System
ISS	Integrated Shipboard System
MARDEZ	Maritime Defense Zone
MCM	Mine Countermeasures
MOU	Memorandum of Understanding
MSS	Mine Surveillance System
NAVGARD	Navy/Coast Guard
NCSC	Naval Coastal Systems Center
NRF	Naval Reserve Force
OR	Operational Requirement
POD	Probability of Detection
PORSH	Portable Equipment Shelter
QUILS	Q-route Underwater Identification and Location System
RAN	Royal Australian Navy
RDT&E	Research, Development, Test and Evaluation
RF	Radio Frequency
ROV	Remotely Operated Vehicle
SLOCS	Sea Line of Communications
SNR	Signal-to-Noise-Ratio
SOG	Speed-Over-Ground



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ABBREVIATIONS/ACRONYMS

TD	Time Delays
TSP	Target Signal Processor
USBL	Ultra-short Baseline
USCG	United States Coast Guard
USN	United States Navy
USCG R&DC	U.S. Coast Guard Research and Development Center
WLB	Seagoing Buoy Tender (USCG)
WYTL	Small Harbor Tug (USCG)

TABLE OF CONTENTS

	<u>Page</u>
EXECUTIVE SUMMARY	xiii
1. INTRODUCTION	i
2. BACKGROUND	2
3. PURPOSE OF TEST	6
3.1 Test Objectives	6
3.2 Test Scenario/Procedure	7
3.3 Evaluation Criteria	7
4. EQUIPMENT AND SYSTEMS	8
4.1 Side Scan Sonar	9
4.1.1 Klein 590 Side Scan Sonar System	9
4.1.2 Sonar Signal Video Display Consoles.....	12
Tracor Model 620/640 TSP	12
Triton Q-MIPS	12
4.2 Display and Data Management	13
4.2.1 QUILS II	13
4.3 Navigation/Positioning.....	16
4.3.1 Radionavigation	16
ACCUFIX 500 Loran-C Receiver.....	16
Differential Loran-C System.....	17
Magnavox MX 4400 GPS Receiver	19
Differential GPS System	19
4.3.2 Positioning.....	19
Sperry SR-50 Ship's Gyrocompass.....	19
TRACKPOINT II Acoustic Tracker.....	21
5. INSTALLATION	22
5.1 Sub-Systems and Equipment	22
5.1.1 Side Scan Sonar	22
5.1.2 Display and Data Management	26
5.1.3 Navigation and Positioning.....	26
5.2 Shipboard Installation	29
5.2.1 65' WYTL.....	30
5.2.2 55' ANB	31
5.2.3 180' WLB.....	33
5.2.4 Portable Equipment Shelter (PORSH).....	34
5.3 Installation Time.....	34

TABLE OF CONTENTS (Cont'd)

	<u>Page</u>
6. TEST RESULTS.....	37
6.1 Vessel Capability/Limitations	39
6.1.1 Interior Working Space.....	39
6.1.2 Deck Space	39
6.1.3 Minimum Speed.....	39
6.1.4 Maximum Speed	40
 6.2 Operational Availability	 40
6.3 Mission Reliability	42
 6.4 System/Operator Interface	 44
6.4.1 Basic Operational Procedures	44
6.4.2 Personnel.....	46
6.4.3 Training	47
6.4.4 Safety	47
6.4.5 Coordination and Communications	51
6.4.6 User-friendliness	51
6.4.7 Vessel Piloting.....	52
 6.5 Operational Suitability.....	 55
6.5.1 Precision Navigation.....	56
Racal Decca HYPERFIX.....	56
Differential Loran-C	57
6.5.2 Side Scan Sonar Procedures: Observed Results	68
6.5.3 Sea-State/Environmental Conditions.....	72
 7. CONCLUSIONS/RECOMMENDATIONS	 74
 REFERENCES	 77
 APPENDIX A - OPERATIONAL TEST PLAN.....	 A-1
Test Evaluator's Daily Log.....	A-13
Operator's Questionnaire.....	A-15
 APPENDIX B - PROJECT PERSONNEL	 B-1
 APPENDIX C - TRACKPOINT II Hydrophone Swing-Arm.....	 C-1

LIST OF ILLUSTRATIONS

<u>Figure</u>		<u>Page</u>
4-1	Integrated Route Survey System (IRSS) Configuration	10
4-2	QUILS II Computer System and Peripherals.....	14
4-3	Differential Loran-C basic concept and system	18
4-4	Major Elements of the USCG R & D Center Differential GPS System.....	20
5-1	IRSS Equipment Installed in 55' ANB and 65' WYTL.....	23
5-2	Klein Side Scan Sonar Towfish and Towcable	24
5-3	Sea-mac 100 Side Scan Sonar Towcable Winch used Onboard 180' WLB.....	25
5-4	Swing-davit Used for Side Scan Sonar Towcable onboard 180' WLB.....	26
5-5	TRACKPOINT II Hydrophone Swing-arm Mounted on Starboard Side of a 65' WYTL.....	28
5-6	TRACKPOINT II Hydrophone Swing-arm Mounted on Port Side of 180' WLB.....	29
5-7	USCGC BOLLARD (WYTL 65614)	30
5-8	55' Aids to Navigation Boat (ANB 55103).....	31
5-9	Integrated Route Survey System (IRSS) Deployed from a 55' ANB.....	32
5-10	USCGC BITTERSWEET (WLB 389).....	33
5-11	View of PORSH From the Forward End.....	35
5-12	IRSS Equipment Installed in PORSH.....	36
5-13	Portable Equipment Shelter (PORSH) Evaluated Onboard a 180' WLB.....	37
6-1	Side Scan Sonar Towfish Launch and Recover Operations.....	48
6-2	USN personnel operating the IRSS onboard a USCG 55' ANB.....	50
6-3	QUILS II Helm Display/Indicator Installed Onboard USCGC Bittersweet (180' WLB).....	53

LIST OF ILLUSTRATIONS (Cont'd)

<u>Figure</u>		<u>Page</u>
6-4	Distance of USCG Vessels Left/Right of Intended Track when Conducting Q-route Survey Operations	54
6-5	Survey Vessel Trackline Plot of Q-route Survey Operations Conducted on 20 October 1988 during New London Q-route Survey Demonstration Project.....	58
6-6	Trackline Plot of Route Survey Leg #1	60
6-7	Differential Loran-C Positions Relative to Differential GPS During Q-route Survey Leg #1.....	61
6-8	Trackline Plot of Route Survey Leg #2	62
6-9	Differential Loran-C Positions Relative to Differential GPS During Q-route Survey Leg #2.....	63
6-10	Trackline Plot of Route Survey Leg #3	64
6-11	Differential Loran-C positions Relative to Differential GPS During Q-route Survey Leg #3.....	65
6-12	Trackline Plot of Route Survey Leg #4	66
6-13	Differential Loran-C Positions Relative to Differential GPS During Q-route Survey Leg #4.....	67
6-14	Relative Frequency of Recorded Side Scan Sonar Contacts (n=63) as a Function of Horizontal Distance from Towfish to Contact.....	70
6-15	Relative Frequency of Recorded Side Scan Sonar Contacts (n=63) as a Function of Altitude of Towfish above Seafloor	71
6-16	Relative Frequency of Recorded Side Scan Sonar Contacts (n=63) as a Function of Towfish Speed Over Ground	73

LIST OF TABLES

<u>Table</u>	<u>Page</u>
5-1 Installation times (work hours) for IRSS by vessel using a 3-person installation team and 4 persons from Ship's force.....	38
6-1 Operational Availability of IRSS onboard a 65' WYTL and a 55' ANB.....	41
6-2 Causes of IRSS-Related off-task periods during underway operations.....	42
6-3 Causes of IRSS-related mission degradation/failures	43
6-4 USCG and USN personnel involved in the operation of IRSS	46
6-5 Relative frequency (%) of side scan sonar contacts reported during varying seafloor topography conditions versus the frequency of seafloor conditions encountered (n=63)	72

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EXECUTIVE SUMMARY

The Q-Route survey mission involves exploratory ocean floor reconnaissance and the location/relocation of mine-like objects along established routes from the entrance of major U.S. ports to the continental shelf.

This report presents the results of a joint U.S. Coast Guard (USCG) - U.S. Navy (USN) Q-Route Survey project conducted in New London, Connecticut during 15 September - 4 November 1988, and 1-4 May 1989. USCG vessels were equipped with commercially- available equipment and systems, and manned by a mix of USCG and USN personnel.

The primary test objectives were to:

1. Evaluate commercially-available side scan sonar, precision navigation, and automated data management systems necessary to accomplish a detailed bottom survey of Q-routes.
2. Evaluate the operational procedures associated with a joint-service approach to Q-route survey operations.
3. Determine the suitability of two USCG vessels, a 55' Aids to Navigation Boat (ANB) and a 65' Small Harbor Tug (WYTL), for Q-route survey operations.

The Integrated Route Survey System (IRSS) configuration employed was comprised of three subsystems: side scan sonar, display/data management, and navigation/positioning.

Side scan sonar subsystem:

- a Klein Model 422S-101HF simultaneous, dual frequency (100/500 kHz) towfish
- a 150 meter lightweight, Kevlar-coated towcable
- a Klein Model 595 HYDROSCAN Recorder (four-channel)
- a Tracor Model 620/640 Target Signal Processor (TSP) or a Triton Q-MIPS Sonar Image Processor

Display/Data Management subsystem:

- QUILS II Integrated Navigation and Data Management System

Navigation/Positioning subsystem:

- Differential Loran-C
- Sperry SR-50 Gyrocompass w/ digital repeater
- Ferranti ORE TRACKPOINT II Acoustic Tracker

RESULTS

Commercially-available systems are suitable for conducting Q-route Survey operations. In order to effectively accomplish a Detailed Route Survey mission, an integrated system configuration comprised of side scan sonar, display/data management system, and navigation/positioning subsystems is required. The USA- manufactured components that were selected by the Royal Australian Navy for their Mine Surveillance System were found to be particularly suitable and effective.

U.S. Coast Guard vessels, including a 55' ANB, a 65' WYTL, and a 180' Sea Going Buoy Tender (WLB), are suitable platforms from which to conduct Q-route survey operations when utilizing side scan sonar. In terms of installing or operating an Integrated Route Survey System (IRSS), there were no significant vessel-related constraints associated with available working space, minimum vessel speed, or electrical power. Given the advantage of a below deck (interior) working space and maximum vessel speed, a 55' ANB is the more capable platform from which to conduct coastal Q-route survey operations. With a portable equipment shelter embarked, a 180' WLB is a highly suitable platform for conducting off-shore Q-route survey operations.

Three technicians working with Ship's force can install IRSS onboard a 55' ANB or 65' WYTL in one working day. This does not include the time required to fabricate the acoustic tracker hydrophone swing-arm assembly. Less time is required to install IRSS onboard a 180' WLB if a Portable Equipment Shelter (PORSH) is embarked with the pre-installed IRSS.

A joint-service approach to Q-route Survey operations that involves both USCG and USN personnel is an effective utilization of existing skills and talent. USCG and USN personnel were quickly able to understand the concept and capably perform route survey operations. Effective results were achieved when assigned USN personnel were assigned to operate the IRSS consoles, while USCG personnel were responsible for piloting the vessel and deploying/recovering the side scan sonar and acoustic tracker hydrophone.

After a brief indoctrination, and with only a moderate amount of onboard training, both USCG and USN personnel were able to effectively operate IRSS during at-sea operations. However, at least two weeks of formal training will probably be required for an individual to become proficient in overall system installation, operation, trouble shooting, and maintenance.

During the two-month underway period that IRSS was operated onboard the 65' WYTL and the 55' ANB, there were 22 instances when IRSS was not able to fully perform a Detailed Q-route Survey Mission. Most were instances classified as "minor failures" which did not result in a significant adverse impact on the overall mission. Only one critical failure occurred that prevented the vessel and crew from performing its mission.

Based on observations made during two months of underway operations, three primary factors impact the effective conduct of route survey operations:

- a. the performance and accuracy of the radio navigation system
- b. Side scan sonar procedures/tactics
- c. Sea-state/environmental conditions

The most critical factor is the capability of the radio navigation system to provide reliable and accurate positioning information.

When used as the precision navigation system for Q-route survey operations, Differential Loran-C provided a predictable, geodetic accuracy of better than 20 meters for 88% of the positioning solutions. At the 95% confidence level, this equates to 23 meters, 2 DRMS (distance root mean square).

The published tactics and procedures on the conduct of Q-route Survey operations when using an integrated navigation/ data management system are not well defined. Factors that appear to influence the likelihood of detecting mine-like objects when using side scan sonar included: the operating frequency of the side scan sonar (e.g., 100 kHz, 500 kHz, or simultaneous 100/500 kHz), range setting, towfish altitude above seafloor, towfish speed over ground, and seafloor topography/composition. Additional controlled testing and validation is needed to derive a more definitive determination of those factors associated with probability of detection and effective search width when using side scan sonar for Q-route Survey operations.

1. INTRODUCTION

This report presents the results of a joint U.S. Coast Guard (USCG) - U.S. Navy (USN) Q-Route Survey project conducted in New London, Connecticut during 15 September - 4 November 1988, and 1-4 May 1989. The overall project goal was to conduct Q-Route survey operations utilizing U.S. Coast Guard vessels, equipped with commercially available equipment and systems and manned by a mix of USCG and USN personnel. The report discusses the results of at-sea operational evaluations intended to measure the effectiveness of an integrated system in meeting Q-route survey mission requirements. In addition, this report presents the observed capabilities and limitations of the various components that comprise each system tested.

Specific test objectives of the New London Q-route Survey Project were:

1. To evaluate commercially available sidescan sonar, precision navigation, and automated data management systems necessary to accomplish a detailed bottom survey of Q-routes.
2. To evaluate the operational procedures associated with a joint-service/interoperability approach to Q-route survey operations.
3. To evaluate the suitability of two USCG vessels, (55' ANB and a 65' WYTL), for Q-route survey operations.

The Q-Route survey mission involves exploratory ocean floor reconnaissance and the location/relocation of mine-like objects along established routes from the entrance of major U.S. ports to the continental shelf.

Q-route survey operations were conducted in accordance with the basic procedures promulgated in the Commander, Mine Warfare Command (COMINWARCOM) Route Survey TACMEMO (Edition 1-89). The Q-route survey data collected during the project have been submitted to COMINWARCOM via Commander, Maritime Defense Zone Sector One, Boston (COMARDEZSEC ONE) for inclusion into the COMINWARCOM Q-route Survey Data Management System.

This project was first proposed by First Coast Guard District on 22 December 1987, and approved as a Select Project by Coast Guard Commandant (G-ER) on 31 March 1988.

2. BACKGROUND

Maritime defense of the United States Coastal regions, a USN mission, received little attention over the past several decades. Prompted by the 1982 recommendations of the Navy/Coast Guard (NAVGARD) Board, the U.S. Coast Guard (USCG) and the U.S. Navy (USN) jointly sponsored restoration and maintenance of a credible national defense posture on each coast in the form of Maritime Defense Zone (MARDEZ) commands. During peacetime, MARDEZ Atlantic and Pacific Commands provide a fully integrated USN/USCG command and control network for military planning, training exercises, and contingency tasking. In times of national emergency or when directed by the President of the United States, USCG forces will augment USN forces to ensure protection of sea lines of communications (SLOCS), coastal area defense, and port/harbor security. Upon activation of MARDEZ, USCG forces will conduct operations in support of anti-submarine warfare (ASW), port security/harbor defense, and mine countermeasures (MCM).

A Memorandum of Understanding (MOU) between the USCG and USN that first established a Route Survey mission for the Coast Guard was signed on 19 May 1982 (Ref. 1). Under this agreement, the operational concept was that:

Reserve and Active CG forces will augment USN MCM assets in peacetime by (1) conducting route survey in designated ports; (2) identifying, listing, and inspecting vessels for the COOP program; and, (3) maintaining precise navigation systems in ports where installed.

In September 1986, a Q-route Survey Equipment and Manpower Test was conducted onboard the USCGC PAPA by Commander, Mine Warfare Command (COMINEWARCOM) using commercially available equipment. This test demonstrated that from a seakeeping perspective, a 180' WLB is "an ideal route survey platform" (Ref. 2). It was also determined that sufficient working space and appropriate billets were available to conduct Q-route survey operations as a secondary mission. However, the basic integrated Q-route survey equipment suite that was tested and evaluated required the operators to rely on manual navigation and contact plotting methods. Without an automated plotting/data management system, post-mission plotting of contacts from the side scan sonar paper records was very time consuming and prone to error. In forwarding

the test report to Commander, Maritime Defense Zone Atlantic (COMUSMARDEZLANT), COMINELWARCOM encouraged "future investigation and testing of possible equipment configurations and survey platforms best suited to the needs of the MARDEZ organization."

At the NAVGARD Board Meeting held on 17 November 1986, the primary topic of discussion related to an overview of MARDEZ issues (Ref. 3). In regard to the USCG's participation in Route Survey operations, Commander, U.S. Maritime Defense Zone Atlantic (VADM D.C. Thompson) reiterated his position that Detailed Route Surveys to support MCM were an important priority.

An Operational Requirement (OR) for MARDEZ Q-route survey equipment (OR No. 188-03-87) was promulgated on 13 November 1987 (Ref. 4). This OR specifically states:

The Coast Guard has identified ships that can contribute to accomplishing the mission if the necessary sonar, navigation system and data processing systems are made available.

In the Capability Desired section of the OR it is stated that:

Precision navigation systems compatible with HYPERFIX system, side scan sonars, and supporting equipments ... are required, in sufficient numbers to allow Coast Guard units to supplement Navy MCM platforms ... Various off-the-shelf systems are available and adequate to the task.

However, in terms of a "minimum desirable capability," the OR specifies that;

(the) system must be able to detect and discriminate mine-like objects to a maximum depth of 300 feet, and to a lateral range of 300 yards. Plotting accuracy should be within 20 yards.

With the exception of the Dowty-Waverley side scan sonar that is being procured for the Naval Reserve Force (NRF) Craft of Opportunity Program (COOP) and for MARDEZ, the system components required for an integrated "MARDEZ Route Survey

System" equipment suite have not been specified. Currently, there are no plans to provide the USCG the Integrated Shipboard System (ISS) that is being installed onboard NRF COOP vessels.

No decision has been made as to which precision navigation system will be used for detailed, nationwide Q-route survey operations. Furthermore, the performance capability of such systems has not been specified (Ref. 5). While the USN has installed Racal Decca HYPERFIX in a number of key ports, there are no plans to install HYPERFIX in all ports or coastal areas that will require detailed route surveys. It now appears that the Global Positioning System (GPS) will ultimately be the system of choice. GPS should be available world-wide within two years, and will provide greater accuracy and coverage than HYPERFIX.

In the fall of 1987, the U.S.Coast Guard Research and Development Center (USCG R&DC) participated in the MARDEZ Exercise AGILE KNIGHT 88 in New London, Connecticut. In addition to conducting pre-exercise Q-route surveys with a side scan sonar, the project team evaluated a "quick response" suite of equipment and software suitable for route survey/MCM operations. (Ref. 6). Operational tests revealed that:

- 1) Precise manual plotting/positioning of side scan sonar contacts from paper records is an exceedingly difficult process --either real-time or post-mission,
- (2) an automated process whereby precise navigation positions are annotated on side scan sonar paper records is crucial,
- (3) an acoustic tracking system for accurate towfish positioning is needed, and
- (4) due to space and minimum speed limitations, a 41' UTB is only marginally acceptable as a platform from which to conduct route survey operations.

On 22 December 1987, The First Coast Guard District Commander submitted a Select Project Proposal entitled: "Development of a CG Q-route Survey Program" (Reference 7). As stated in the proposal, the two primary objectives of the project would be to:

- (1) evaluate the use of commercially-available side scan sonar and precision navigation systems required to accomplish a detailed bottom survey, and

- (2) develop and/or evaluate tactics associated with a joint-service approach to Q-route survey operations that involves the employment of a USCG 55' ANB manned by a mix of CG and USN Reservists.

The Select Project Proposal was endorsed by the USCG R & D Center with the recommendation that a main thrust of the project be to evaluate options for improved tactics and systems. In this regard, a number of techniques and capabilities would be evaluated including: automated search planning; accurate positioning of the search vessel and towfish; automated collection/display of positional and side scan sonar data; and, archiving, recall, and analysis of contact and navigational data.

A USCG Commandant message (Ref. 8) on 3 June 88 further expanded on the goals and scope of the project:

The project goal is to conduct a joint-service Q-route survey and process/equipment evaluation in New London, CT using USCG vessels equipped with USN-developed and commercially available route survey systems ... our [USCG] interest is to evaluate several side scan sonars, precise navigation, and computer assisted plot/display systems--including ISS--in an operational environment.

It was originally expected that the Navy would provide the three primary components of the COOP-Route Survey equipment suite (ISS, Dowty-Waverley sidescan sonar, and HYPERFIX) to be used during the project. For a variety of reasons associated with status of development and availability, none of these systems were provided or evaluated during the fall 1988 project.

As a follow-on to the fall 1988 project, an at-sea evaluation of additional systems and tactics suitable for conducting Q-route survey operations was conducted 1-4 May 1989. The two primary objectives of this effort were to:

- 1) conduct a simultaneous evaluation of HYPERFIX, Loran-C, and Differential Loran-C as precision navigation systems over the entire length of the New London Q-route.
- 2) evaluate a portable equipment shelter suitable for conducting Q-route survey operations when deployed onboard a USCG buoy tender (180' WLB).

This underway period also provided an opportunity evaluate the use of a towing winch for the side scan sonar towfish and towcable.

As discussed in USCG COMDTINST 7110.1A, MDZ Resource Requirements (Ref. 9), in order to achieve a desirable level of interoperability, there is a need for inter-service coordination associated with MARDEZ Research, Development, Test and Evaluation (RDT&E). To accomplish this goal, close liaison was established with the following U.S. Navy commands: Commander, Mine Warfare Command (COMINEWARCOM); Naval Sea Systems Command (NAVSEA-PMS 407D); Commander, U.S. Maritime Defense Zone Atlantic (COMUSMARDEZLANT); and, Naval Coastal Systems Center (NCSC), Panama City, FLorida. In addition to First Coast Guard District, USCG commands and offices involved in the project included: USCG Group Long Island Sound; USCG Group Woods Hole; Commandant (G-OD), Office of Defense Operations, USCG Headquarters.

3. PURPOSE OF TEST

The overall purpose of this project was to conduct an operational evaluation of the Integrated Route Survey System (IRSS) when installed on USCG vessels and operated by USCG/USN personnel.

3.1 Test Objectives

Specific test objectives related to the operational suitability and effectiveness of the installed, integrated system included:

- o vessel capability
- o operational availability and reliability
- o system/operator interface
- o human factors
- o training
- o safety
- o technical documentation
- o operational suitability

3.2 Test Scenario/Procedure

As specified in the Test Plan (Appendix A), the primary focus of the project was to evaluate systems and procedures in an operational environment rather than a technical evaluation of any specific equipment/system under tightly controlled conditions. In this manner, the IRSS was evaluated in terms of the types of personnel who would be eventually using the system.

Testing and evaluation procedures were conducted onboard a 65' WYTL and a 55' ANB in two phases: (1) initial equipment/system installation and checkout, and (2) at-sea, underway operations. Information gathered by the Test Director and Evaluators provided both qualitative and quantitative data regarding the performance of IRSS, as well as data that could be used to evaluate the overall operational suitability and effectiveness of the equipment, personnel, and platform (Appendix A). For each test objective, the Test Plan provided specific guidance on evaluation criteria, data collection procedures, and data analysis. Various forms of data collection included a Test Evaluator's Daily Log and an Operator's Questionnaire (Appendix A). All systems installation and underway operations were monitored by the Operational Test Director and/or a Test Evaluator.

3.3 Evaluation Criteria

Criteria for evaluation during the various evolutions associated with Q-Route Survey operations included:

1. Side scan sonar towfish deployment/recovery
 - required personnel (number, rate)
 - time required to deploy/recover
 - maximum sea-state
 - vessel speed (minimum/maximum)
2. Acoustic Tracker Hydrophone Launch/Recovery
 - required personnel (number, rate)
 - time required to launch/recover
 - maximum sea state
 - vessel speed/maneuvering

3. Helm Display/Piloting
 - coxswain (rate, experience level)
 - user-friendliness
4. Tactical/Data Management Console
 - operator personnel (rate, training)
 - user-friendliness (man-machine interface)
5. Side scan Sonar Recorder/Video Console
 - operator personnel (rate, training)
 - user-friendliness

Each system consisted of a unique combination of vessel configuration, equipment suite, operators and personnel, and procedures and tactics. We evaluated each in terms of:

- vessel speed (minimum/maximum)
- vessel handling/maneuverability
- maximum sea state
- currents, wind
- hazards/interference
 - surface vessel traffic
 - buoys (nav aids, lobster, fishing)
 - sub-surface obstructions (lobster trap line, fishing nets, etc.)
- minimum/maximum time on task

4. EQUIPMENT AND SYSTEMS

Commercial side scan sonars have been shown to be a highly effective tool for conducting a wide variety of hydrographic survey operations (Ref. 13). Light-weight, highly portable, off-the-shelf availability, and dependable performance are attributes that have lead an increasing number of Navies to use side scan sonar for underwater surveillance operations. When integrated with a display/data management system and a navigation/positioning system, a side scan sonar can be particularly effective for conducting a route survey mission (Ref. 17 & 18).

The basic system configuration that comprised the IRSS used in our tests was patterned after the Royal Australian Navy's (RAN) Mine Surveillance System (MSS). The RAN MSS selection was made after extensive, at-sea evaluations in 1988 that compared the capability and performance of some of the most advanced, commercially-available navigation, data management, side scan sonar, image processing, and acoustic tracking systems available on the world market. All components selected by the RAN for their MSS system are manufactured in the United States. The only significant difference between the RAN MSS configuration and the system we tested was the use of Loran-C and GPS as the navigation/positioning sensors for IRSS.

Figure 4-1 shows the IRSS configuration (block diagram) that was evaluated. Functionally, the system consists of three sub-systems:

- 1) Side scan Sonar
- 2) Display and Data Management
- 3) Navigation/positioning

The following sections briefly describe the various components that comprised the three sub-systems. For a more detailed description of the specific equipment or sub-systems, the Operator's Manual published by the manufacturer should be consulted. Chapter 5 describes the time and effort required to install the IRSS and the various equipment components that comprised the IRSS installed onboard the different vessels.

4.1 Side Scan Sonar - Sub System

Side scan sonar systems have three basic components: a towfish, towcable, and a graphic recorder. In addition, more advanced systems have a computer-aided video display/target selection console.

4.1.1 KLEIN 590 Side Scan Sonar System

The Klein Side Scan Sonar System included a Model 595 combined side scan sonar transceiver and high resolution graphic recorder, a simultaneous, dual-frequency 100/500 kHz side scan sonar towfish, a 150 meter length of light-weight towcable, and a towfish depressor (vane). Two different computer-aided video display consoles were used in con-

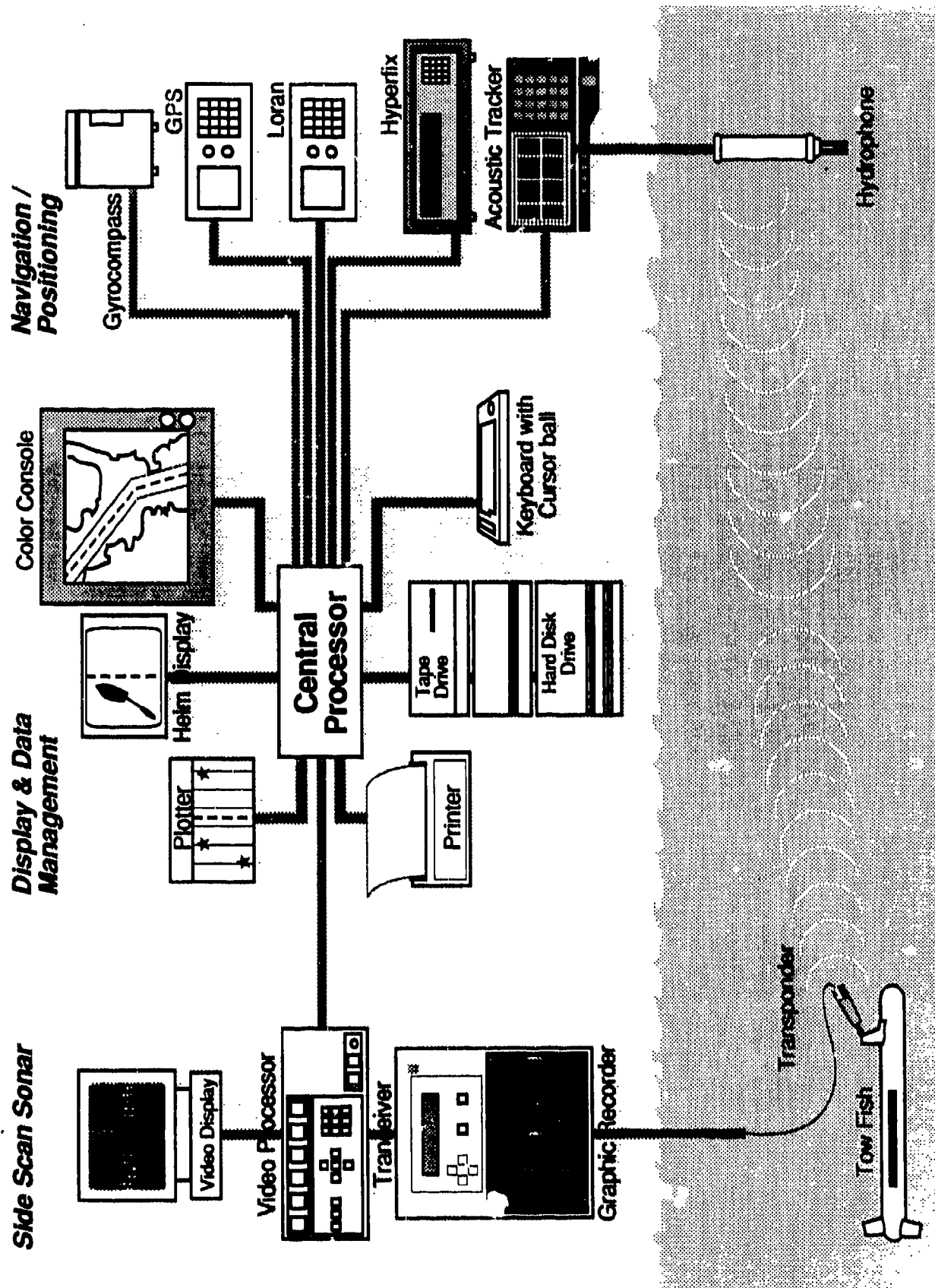


Figure 4-1. Integrated Route Survey System (IRSS) Configuration

junction with the Klein 590 Side scan Sonar System: a **TRACOR TSP** and the **TRITON Q-MIPS**. For other missions besides Q-route survey applications, the **KLEIN 590** system can be used as a separate, independent system.

Towfish - The Klein Model 422S-101HF towfish was used. Towfish accessories included a circular tailfin and a depressor vane that could be used for deep water operations. This simultaneous 100/500 kHz dual frequency towfish was particularly useful in that effective sonar range and resolution could be optimized under a wide variety of conditions. While the 100 kHz sensor usually gave the best range performance (often > 150 meters), the 500 kHz provides the highest resolution potential for relatively small-sized objects (less than 2 meters in length). Since the 500 kHz is generally limited in range to less than 100 meters due to attenuation of the acoustic signal in the water, using the 100 kHz and 500 kHz frequencies simultaneously, increases the probability of detection for objects that exhibited mine-like characteristics (shape and size) under a wide variety of bottom and acoustic conditions.

Towcable - A 150 meter, lightweight towcable assembly was used onboard the 55' ANB and the 65' WYTL. The 4-channel, Kevlar coated cable was approximately 5/8" diameter. The entire length of cable (150m) weighed approximately 95 lbs. Even when wet, the towcable was not particularly slippery, and could be readily gripped when deployed and recovered by hand. During two months of daily operation, the cable suffered very little damage, wear, or abrasion.

Graphic Recorder - The Klein Model 595 HYDROSCAN Recorder included accessory cables, spindles, and recording paper. Printing is done on a plastic-based, thermal paper rather than the so-called "wet paper" trace used in earlier side scan recorder models. Utilizing a fixed thermal printing head, 203 dots per inch of resolution is achieved. This simultaneous, dual frequency (100/500 kHz) recorder is capable of processing four channels of data at one time. Using the control menu, two or four channels of data can be selected and displayed either as a hard-copy paper record or on the video display console. This data can also be output through a tape port for recording on magnetic tape.

Relatively little training is required for an operator to use the Klein HYDROSCAN Recorder. All recorder functions are accessed and set using just six control keys and a LCD menu display. Following initial setup, the recorder utilizes default settings after each

power-up. Almost all tuning is automatically controlled by the Recorder's microprocessor. Since slant range correction and speed correction are standard (default) settings, most data are displayed in a "corrected format." The Recorder also provides automatic or manual annotations on the record, including time/date, position, and event number.

4.1.2 Sonar Signal Video Display Consoles

Two different computer-aided video display consoles were used as components of Klein 590 system:

- o **TRACOR Model 620/640 Target Signal Processor (TSP)**
- o **TRITON Q-MIPS Sonar Image Processing System**

The **TRACOR Model 620/640 TSP** system was specifically developed to be used in conjunction with the Klein 590 Side scan Sonar System. The TRACOR TSP (Target Signal Processor) was used onboard both the 65' WYTL and the 55' ANB. The equipment components included:

- o a digital signal image and navigation processor
- o a high resolution CRT with a touch screen
- o a 8mm cassette tape drive.

The TRACOR TSP, and other similar systems, offer several advantages to relying solely on a side scan graphic recorder. When integrated with an integrated navigation data management system (e.g., QUILS II) an operator can accurately mark and determine the position of objects of interest. The color console greatly enhances the probability of detection for relatively small-sized objects under varying bottom types and sonar conditions. A screen zoom-in/out capability, and the use of a touch screen to mark and measure the size of the selected object facilitates the identification, marking, and classification various types of objects.

The **TRITON Q-MIPS Sonar Image Processing System** was similar in function to the TRACOR TSP, in terms of processing and displaying digital input received from the side scan sonar recorder. This equipment suite was evaluated only onboard the 180' WLB.

The Triton Q-MIPS components include:

- o a 4-channel digitizer, array processor, and video processor
- o high resolution color display monitor
- o a dual-disk optical drive.

4.2 Display and Data Management - Sub-System

4.2.1 QUILS II

The QUILS II Integrated Navigation and Data Management System manufactured by Meridian Ocean Systems, Inc. was the primary "integrator" for the IRSS equipment suite. QUILS II (**Q**-route **U**nderwater **I**dentification and **L**ocation **S**ystem) simultaneously collects, integrates, and stores the side scan sonar data; passes information between the various sub-systems; and, generates helm and tactical displays. As an Integrated Navigation System (INS), it is compatible with all commercial side scan sonar, precision radio navigation, and acoustic tracking systems. In addition to being used for conducting a route survey mission, QUILS II has been used for seafloor-mapping, hydrographic survey, search and recovery, and remotely-operated vehicle (ROV) operations.

The primary hardware components of the QUILS II system include:

- o Hewlett-Packard HP-330 computer (32 bit CPU and peripherals)
- o 8mm cassette tape drive
- o 40 mb hard disk drive
- o high-resolution color console (with keyboard and trackball cursor)
- o color drafting plotter (A-3 size)
- o color inkjet printer
- o helm display monitor and touch key pad

Figure 4-2 is a diagram of the QUILS II system and peripherals.

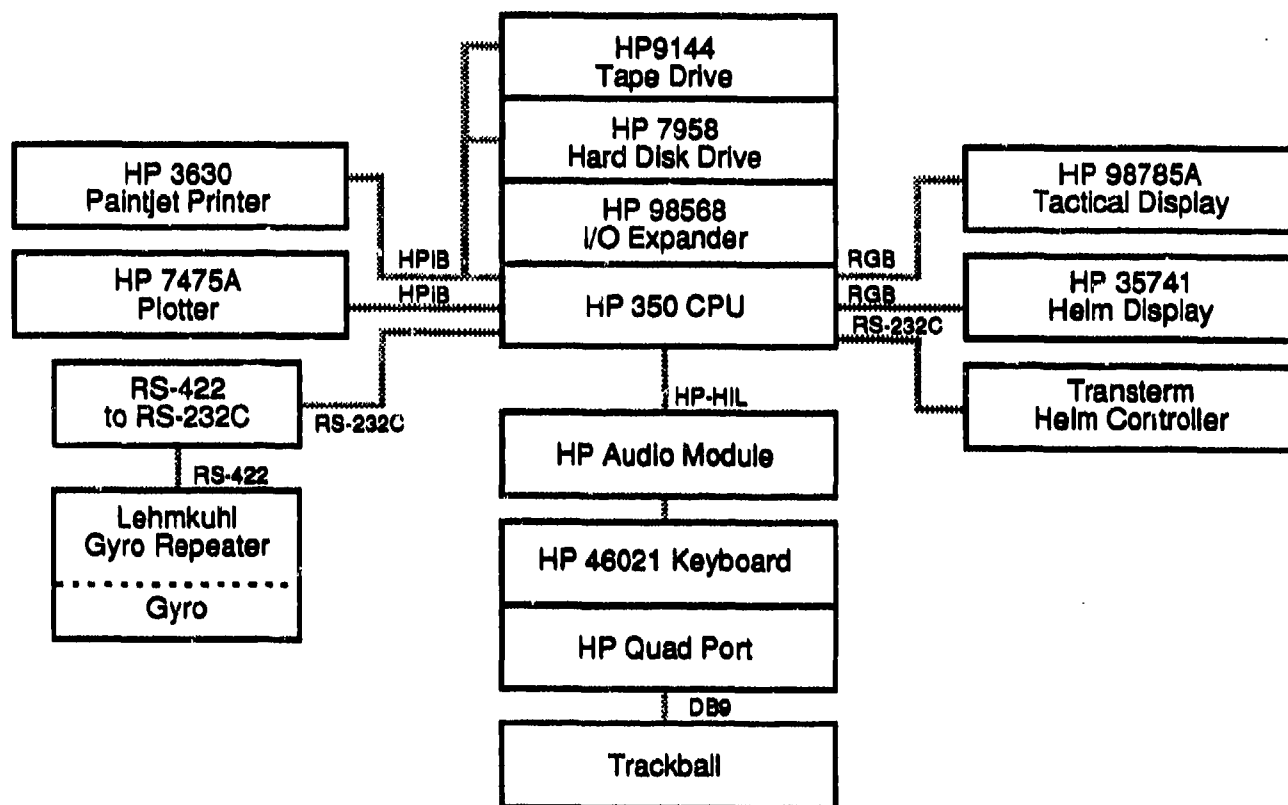


Figure 4-2. QUILS II Computer System and Peripherals

Utilizing a relatively sophisticated systems integration approach, QUILS II provides a single, integrated system that allows an operator to conduct high accuracy side scan sonar surveys, digitize and classify sonar contacts as they are observed in real-time, and analyze all contact/target information (both current and historical) via an interactive color graphics console. QUILS II functional operations fall into three general categories: mission planning, real-time navigation/data collection, and post-mission analysis.

Mission Planning includes the following functions:

- o electronic chart set-up
- o track-line generator
- o plotter chart generator
- o equipment ID data base
- o geodetic parameter set-up
- o vessel outline and parameters
- o daily log and set-up page
- o report generator
- o navigation planning/coverage display

Real-time Navigation and Data Collection - During underway operations, the QUILS II:

- o performs real-time digitizing and mapping of sonar contacts
- o provides a tactical display of electronic chart, historical targets, new contacts, tracklines, and vessel/fish position
- o has an independent graphics display for helmsman
- o auto-records the vessel/towfish track
- o automatically records and displays contacts marked by the video display/TSP
- o can perform rapid zoom-in/out and set screen center with a single function key
- o tracks position of towfish [with ultra-short baseline (USBL) acoustic tracker] and vessel simultaneously
- o can compute range/bearing to any contact, navigation way point, or charted object
- o simultaneously monitors a primary and secondary radio navigation system
- o uses a six-stage Kalman navigation filter with variable smoothing

Post-Mission Analysis capabilities and functions include:

- o an interactive graphics analysis of track, contacts, and targets
- o the ability to recall and display (on the TSP) the video sonar image of selected contacts/targets from the tactical display console
- o a statistical proximity analysis function that can be used to match the location of a new contact with previously designated (historical) targets
- o a display of sonar coverage (swept path)
- o a "security protected access" for edit/storage/backup
- o a comprehensive report generator (plotter and printer)

4.3 Navigation/Positioning - Sub-System

This IRSS sub-system was comprised of two radio navigation receivers, a Differential Loran-C System, an ultra-short baseline (USBL) acoustic tracker, and a ship's gyrocompass that simultaneously determined the position (i.e., latitude/longitude) of both the vessel and of the side scan sonar towfish. The equipment that comprised this sub-system can be further divided into two functional components:

1. Radionavigation

- o ACCUFIX 500 Loran-C Receiver
- o Magnavox MX 4400 GPS Receiver

2. Positioning

- o Sperry SR-50 Ship's Gyrocompass with Lemhkuhl LR-60 Digital Repeater/RS-232 Interface
- o Ferranti ORE TRACKPOINT II Acoustic Positioning System (USBL Acoustic Tracker)

4.3.1 Radionavigation

An **ACCUFIX 500** was the Loran-C receiver used during the Q-route survey project. Manufactured by Megapulse, Inc., this is the same high precision/survey grade Loran-C receiver that is installed onboard U.S. Navy MCM vessels and Craft-of-Opportunity

(COOP) vessels. The Accufix 500 tracks the master and up to four secondary Loran-C stations with an accuracy better than 0.025 microseconds. It has a RS-232 data output port that can be used for data recording and for a Differential Loran-C mode of operation.

Similar to most commercially-available Loran-C receivers, the functional procedures required to operate the Accufix 500 are relatively simple. After initial power-on, the operator selects the Loran-C chain Group Repetition Interval (GRI) for the geographic area where operations are to be conducted (e.g., Northeast U.S. 9960 Chain). Two secondary stations are then selected. This selection is normally based on the best geometry and the signal-to-noise-ratio (SNR) of the secondary pairs. A third and fourth secondary station could be selected as well. After the proper sequence of status information is displayed, no further action on the part of the operator is required. As a sub-system component of IRSS, the Loran-C receiver unit requires almost no operator intervention. After initial power-up, if the Accufix 500 is turned off (or loses power), it recalls the previous GRI and secondaries and resumes operation.

A **Differential Loran-C (DLC)** system was used as the primary navigation sensor for routine route survey operations. During September - November 1988 and 1-4 May 1989, USCG Research and Development Center (R&DC) provided a prototype DLC and a Differential Global Positioning System (DGPS) in support of the Q-route Survey Demonstration Project. Figure 4-3 is a diagram of the basic DLC system and concept.

A reference Loran-C receiver is placed at a high order survey control point (reference location). By comparing the known location with that predicted by the received Loran-C signals (called time delays or TDs), corrections can be determined. These differential corrections are then broadcast to vessels at sea, who can use them to improve their position solutions. For the fall 1988 surveys in Long Island Sound and Block Island Sound onboard the 55' ANB and 65' WYTL, the RTCM SC-104 format was used to generate a UHF broadcast which contained both the DLC and DGPS correction messages. For the May 1989 follow-on trials onboard the USCGC BITTERSWEET, corrections were broadcast in RTCM SC-104 format from the Marine Radiobeacon (MF broadcast) at Montauk Point, Long Island, New York.

The basic shipboard system consisted of an ACCUFIX 500 Loran-C receiver, a RF modem/demodulator for the RTCM broadcast, and a HP-220 computer. The computer

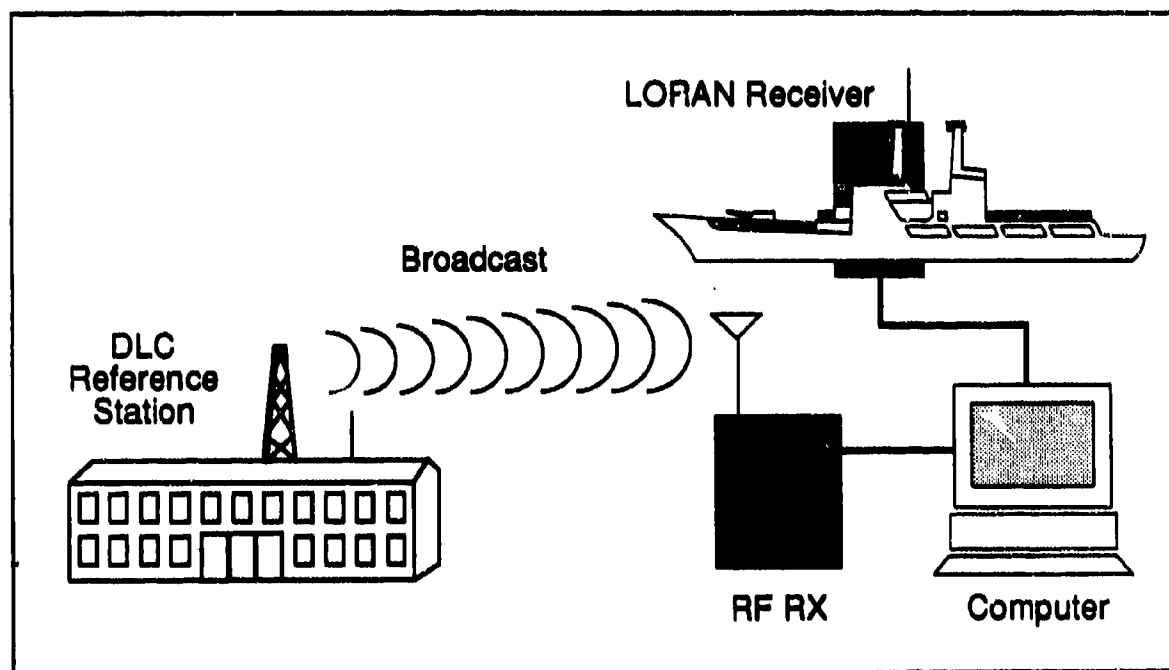
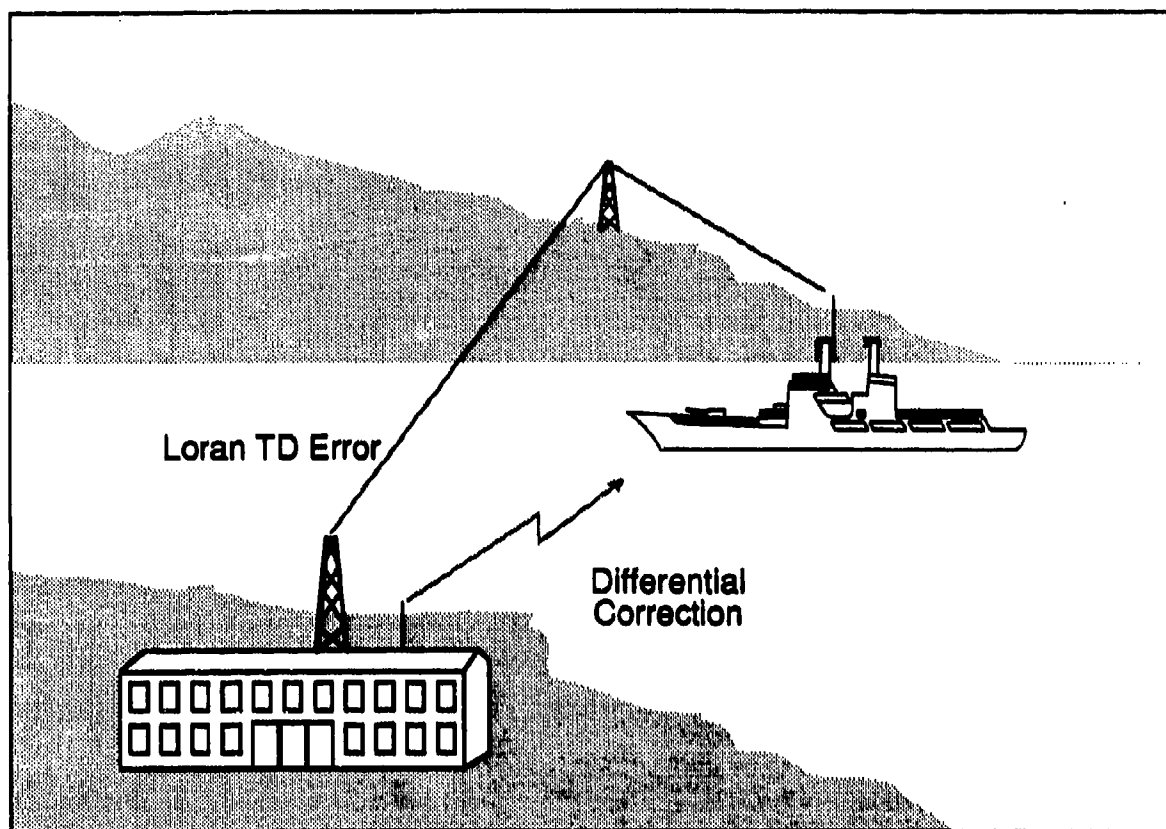


Figure 4-3. Differential Loran-C Basic Concept and System

takes the DLC corrections received from the reference station and applies them to the TDs received by the ACCUFIX 500. The corrected TDs are then provided to the QUILS II via an RS-232 port. If required, the computer can also convert the TDs to latitude/longitude positions using Sodano's iterative method. The computer was also used in conjunction with DGPS to create a file of Loran-C additional secondary factor (ASF) corrections in the immediate area where Q-route survey operations were conducted. This waypoint file of ASF corrections was collected for each mile of the Q-route that was surveyed.

A **Magnavox MX 4400 GPS Satellite Positioning and Navigation System** was the GPS receiver unit used in conjunction with Differential GPS as the positioning truth system. During those periods when at least 4-satellite coverage was available, the MX 4400 receives GPS Navstar signals. These signals are directed to a two-channel C/A code receiver to determine a three-dimensional position solution (latitude, longitude and altitude). The basic system consists of a satellite signal antenna, a preamplifier/downconverter (incorporated into the antenna), and a receiver console. The console includes a front panel keypad and display that can be used to determine present position, speed, course over ground, heading, set and drift, waypoint locations, and estimated time of arrival. The operation of the MX 4400 is by a menu-driven fluorescent display. All calculations are performed automatically.

A **Differential GPS System (DGPS)** was provided and operated by R&DC personnel and served as a "truth positioning" system. Similar in concept to DLC, DGPS compared the signals received at a reference station, and sent corrections via a RF communications link to the MX 4400 GPS receiver onboard the Route Survey vessel (Figure 4-4). The design and operation of DGPS is described in more detail in Reference 12. That report discusses how real-time dynamic positioning accuracies of 5 meters, 2 DRMS can be achieved using DGPS.

4.3.2 Positioning

A **Sperry SR-50 Ship's Gyrocompass** was used to generate a vessel heading reference for the IRSS. In order to convert the analog signal from the gyrocompass to a digital output for the QUILS II computer (CPU), a Lemhkuhl LR-60 Master Repeater was used. The Sperry SR-50 includes a master gyrocompass and a static inverter. The gyrocompass unit consists of a wire-suspended, three degree-of-freedom gyroscope. The

Major Elements of a USCG DGPS Service

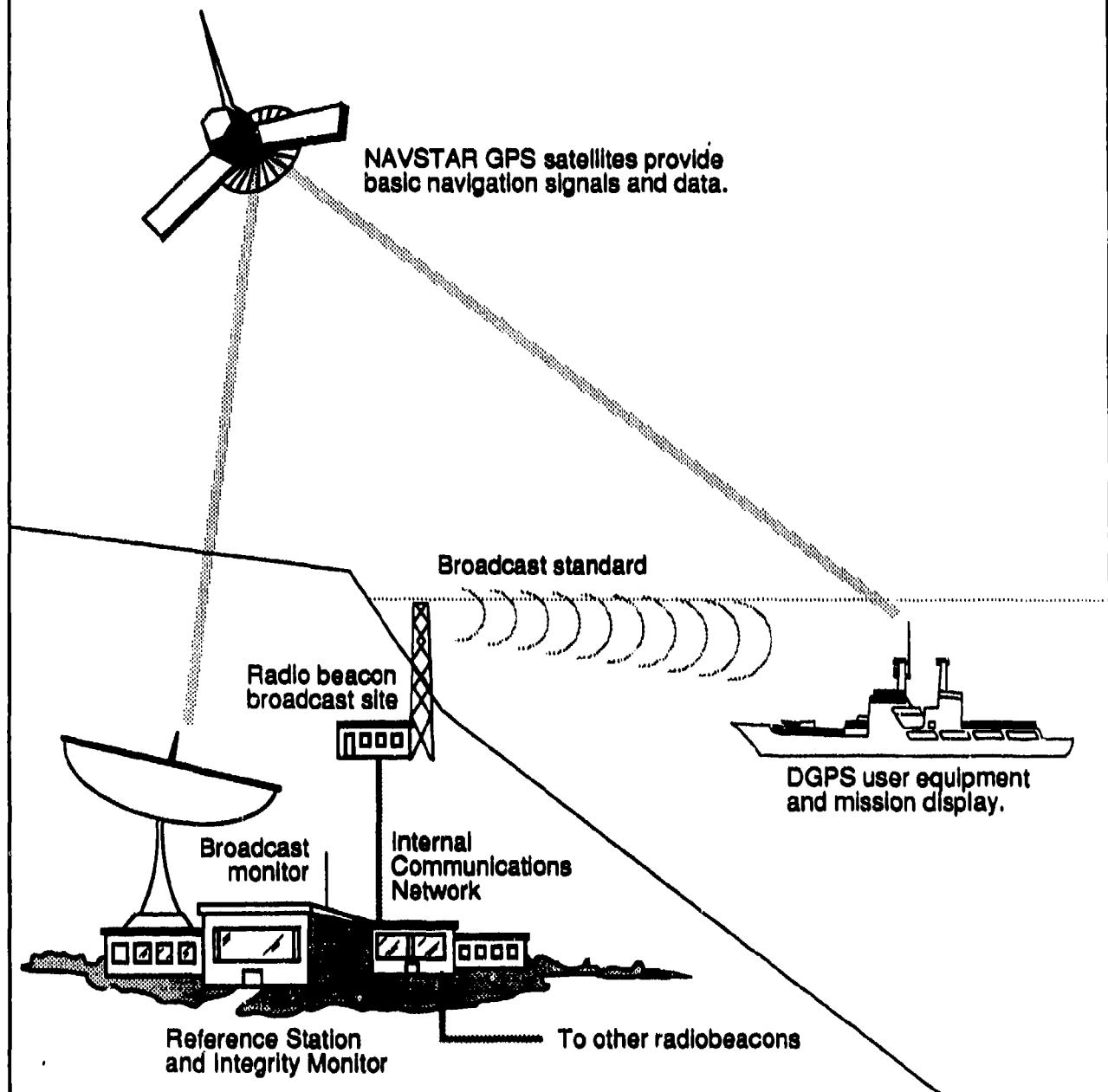


Figure 4-4. Major Elements of the USCG R&D Center Differential GPS System

static inverter provides power conversion from a 24 VDC power source and contains the operating controls and indicators. The Lemhkuhl LR-60 digital repeater decodes the gyro transmission signals, displays digital heading data, and provides a digital output via a RS-232 port to the integrated navigation data management computer (QUILS II).

Once activated and stabilized, the Sperry SR-50 gyrocompass system requires little in the way of operator attention. If daily operations are the norm, the gyrocompass should be allowed to operate continuously over a 24-hour period since approximately four hours of settling time are required. For less frequent operations, SR-50 has a timer which can automatically activate the system at a preset time.

A Ferranti ORE TRACKPOINT II Acoustic Positioning System was used as an ultra-short baseline (USBL) acoustic tracker. The purpose of this sub-system component is to determine the precise position of the side scan sonar towfish relative to the survey vessel. As a positioning system, it accepts a vessel heading input from a gyrocompass and is able to receive and decode acoustic telemetry signals from a transponder, responder, or pinger. In addition to being used in conjunction with side scan sonar/hydrographic survey applications, the TRACKPOINT II has been used to track remotely operated vehicles (ROVs), manned submersibles, and both scuba and hardhat divers.

The basic TRACKPOINT II system consists of:

- o a command/display console
- o a hydrophone
- o an interconnect cable
- o acoustic tracking beacon (pinger/transponder)

In operation, the TRACKPOINT II emits an interrogation pulse which the acoustic transponder receives and replies with its own discreet acoustic signal. When the system receives the transponder's reply, it then calculates the slant range to the transponder, using a phase comparison technology to determine both the azimuth and depression angle for the incoming signal. Bearing accuracy is normally ± 1.5 degrees with a slant range accuracy of \pm one meter. On the console, the location of the transponder (mounted on the towfish) is displayed and updated every two seconds. The display also indicates both graphically and alphanumerically the range, bearing, and depth (X, Y, Z coordinates) of the

transponder to the survey vessel. For the IRSS system, this telemetry information was automatically input to the QUILS II.

Further detail on the installation and operation of the TRACKPOINT II hydrophone swing-arm assembly is provided in Section 5.1.3 and in Appendix C.

5. INSTALLATION

The amount of time and effort required to install the Integrated Route Survey System (IRSS) onboard different types of USCG vessels was an important evaluation factor of the Q-route Survey Demonstration Project. Equipment installation was performed as a cooperative effort by technicians and engineers from the USCG Research & Development Center and by vessel crew members. Some technical assistance was also provided by several equipment manufacturers during the initial installation, calibration, and checkout of the various system equipment and components. Final system integration was performed on each of the three vessels utilizing contractor support from the manufacturer of QUILS II, Meridian Ocean Systems, Inc.

The following sections describe what is involved in terms of installing the various sub-systems, equipments, and components that comprised IRSS (Figure 5-1).

5.1 Sub-Systems and Equipment

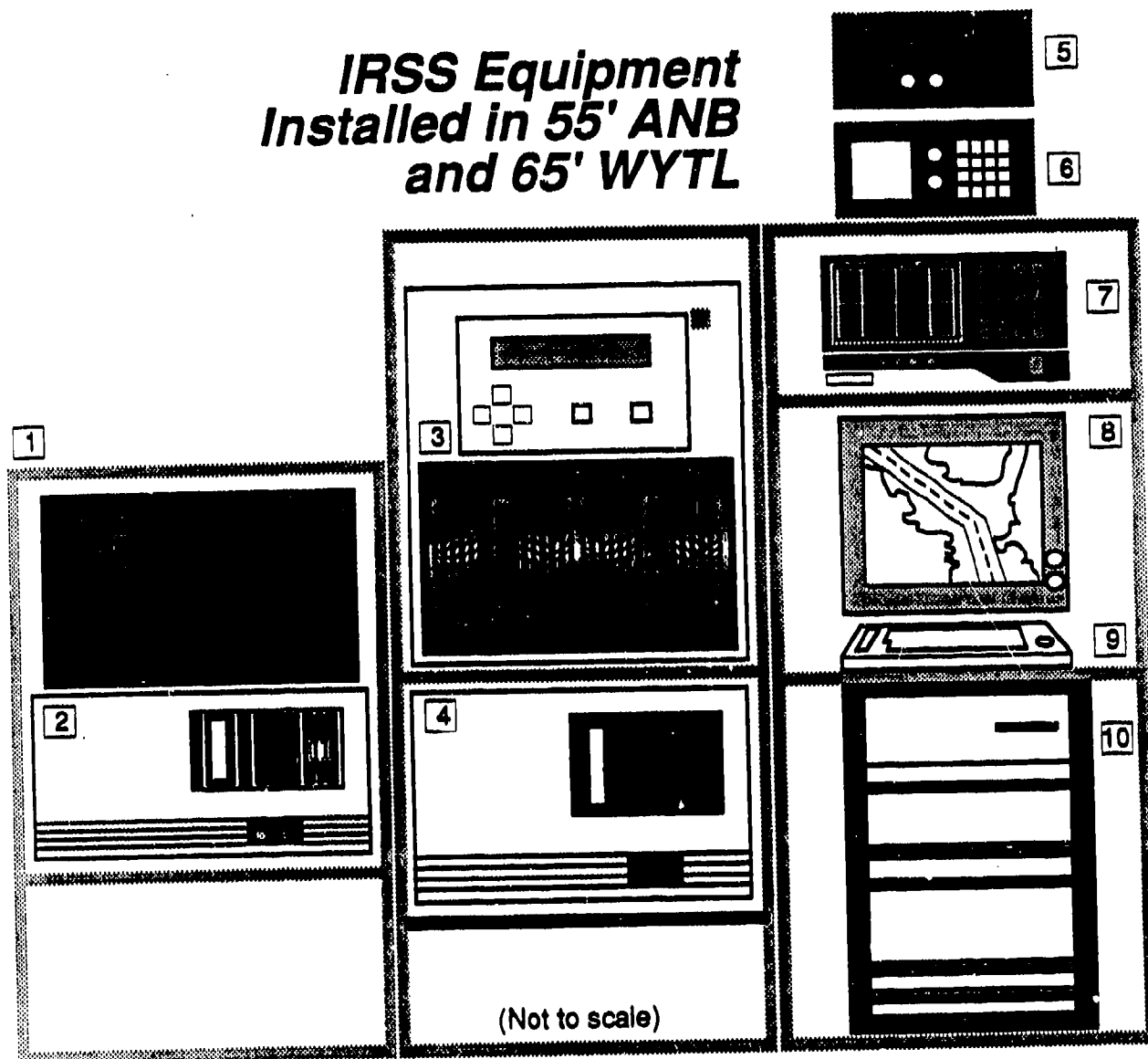
5.1.1 Side Scan Sonar

Klein Towfish and Towcable - The Klein towfish and towcable were rigged on the fantail of the 65' WYTL and 55' ANB (Figure 5-2). The towfish has stabilizing tail fins that are designed to break away in the event of a snag. Attachment points located in the rear and nose of the towfish were also used to rig a safety line from the towfish to the towline. A Klein grip that was fastened to a cleat with a short length of line was used to hold the towcable during towing operations.

Klein Graphic Recorder - The graphic recorder was mounted in a standard 19" equipment rack and installed with the other interior ship IRSS components.

Video Display Consoles - For both the TRACOR TSP (65' WYTL and 55' ANB) and the TRITON Q-MIPS (180' WLB) the processor and tape drive units were mounted on the 19"

IRSS Equipment Installed in 55' ANB and 65' WYTL



1. Video Display
2. Video Processor (TSP)
3. Sonar Receiver / Graphic Recorder
4. 8mm Cassette Recorder
5. GPS Receiver

6. Loran-C Receiver
7. Acoustic Tracker
8. Color Console
9. Keyboard w/cursor ball
10. Tape Drive w/ Hard Disk Drive

Figure 5-1. IRSS Equipment Installed in 55' ANB and 65' WYTL

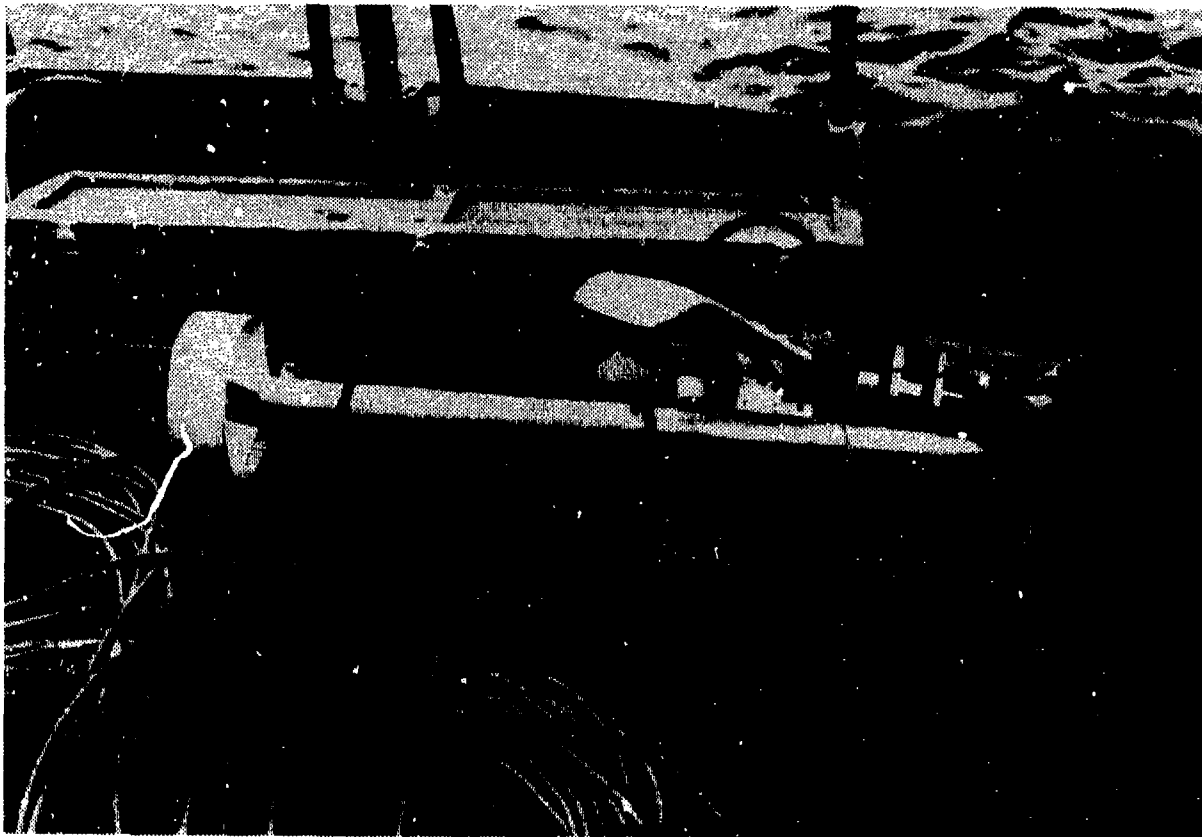


Figure 5-2. Klein Side Scan Sonar Towfish and Towcable

equipment racks with the other IRSS sub-systems. The CRT display console was too large to be mounted into the 19" equipment racks, and was mounted on a separate shelf.

Towing Winch - The winch and the towing cable reel was delivered to the dock on a pallet and weighed approximately 750 lbs (Figure 5-3). It was loaded onboard the USCGC BITTERSWEET (WLB 389) using a crane car. The winch was positioned aft on the port side of the weather deck, approximately half-way between the ship's own winch and the towing bit. The tow cable winch was angled slightly outboard and secured to the deck by spot welding the corners of the winch frame. Ship's force fabricated a simple swing-davit which was attached to the rail aft of the towing winch (Figure 5-4). A 12" diameter snatch-block with a cable counter was then mounted on this davit for leading the towing cable overboard. Electrical power to the towing winch was provided by wiring a 220V power cable from the electrical service box from the ship's own winch. The remote control unit cable for the towing winch was routed to the PORSH on the buoy deck. This control unit consisted of two momentary switches for the towcable in/out control. In addition, the cable counter device mounted on the snatch block was wired to a simple indicator display located in the PORSH. The entire installation process was completed by ship's force in approximately five hours.

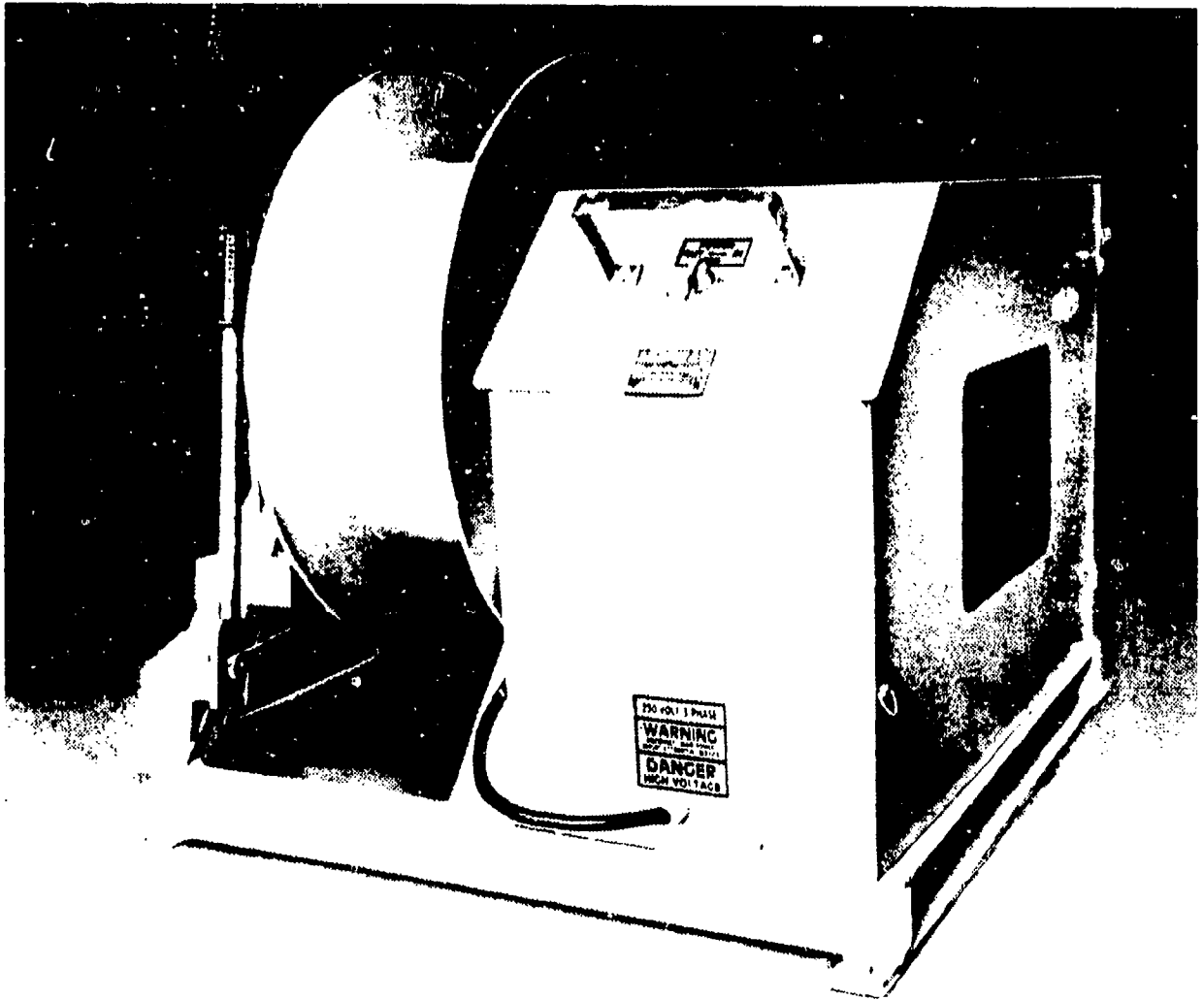


Figure 5-3. SEA-MAC 100 Side Scan Sonar Towcable Winch Used Onboard 180' WLB

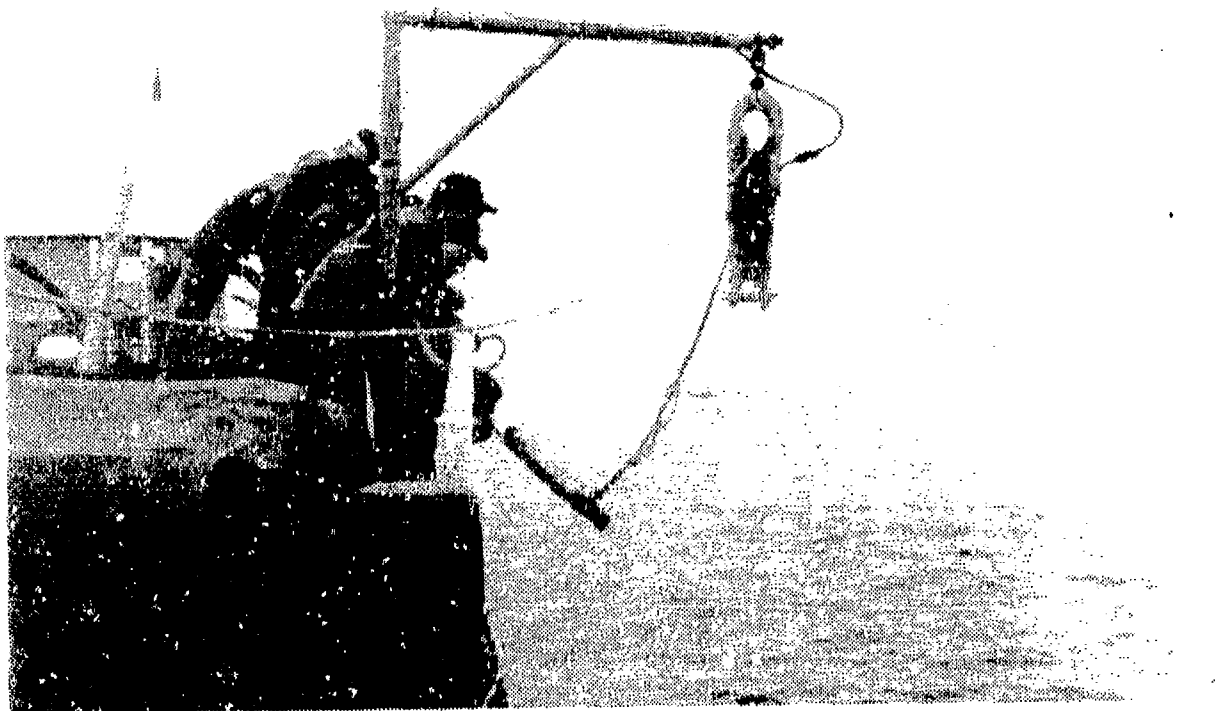


Figure 5-4. Swing-davit Used for Side Scan Sonar Towcable Onboard 180' WLB

5.1.2 Display and Data Management

QUILS II - Installation of the QUILS II equipment suite onboard either the 55' ANB, 65' WYTL or in the Portable Equipment Shelter (PORSH) took less than three-work hours. However, the amount of time needed to "integrate" QUILS II with the other sub-systems and components was over 15 work-hours. For all installations, the QUILS II integration was performed by engineers and technicians from Meridian Ocean Systems.

5.1.3 Navigation and Positioning

ACCUFIX 500 - There are three basic components to this receiver system: antenna, antenna coupler and lead, and receiver unit. To insure proper performance of the Accufix 500 (or any Loran-C receiver), both the antenna coupler and the receiver chassis should be properly grounded. The time required to install all three components onboard either the 55' ANB, 65' WYTL, or the 180' WLB was approximately one work-hour.

Magnavox MX 4400 - The MX-4400 GPS receiver system is comprised of a small plastic covered antenna (15" in height), an antenna cable, and console unit. Similar to the ACCUFIX 500 installation, approximately one hour was required for a technician to install this system.

Sperry SR-50 Gyrocompass - The amount of area required to install a Sperry SR-50 is less than 2'x 2'x 2'. Installation sites included: a storage locker aft of the pilot house on the 65' WYTL, the workshop deck onboard the 55' ANB, and a counter-top in the PORSH onboard the 180' WLB. Since a pilot house display of the gyrocompass heading was not required when using the IRSS, the LR-60 digital repeater was co-located with the master gyrocompass. The amount of time required to install the gyrocompass system onboard the 55' ANB or 65' WYTL was 4-6 hours. Installation in the PORSH took only 2 hours.

TRACKPOINT II Acoustic Tracker Hydrophone - To operate effectively, the TRACKPOINT II ultra-short baseline (USBL) acoustic tracker hydrophone must be mounted below the keel of a vessel. This is essential in order to achieve a clear acoustic path from the hydrophone to the transponder mounted on the side scan sonar towfish that is being towed astern. There are two alternatives to mounting the hydrophone to a vessel. One option is an "over-the-side" swing-arm assembly suitable for slow-speed, low sea-state operations (i.e., less than 8 kts). Another option is to use a smaller-sized hydrophone which is passed through a 3-inch gate valve in the ship's hull. Since the swing-arm assembly was a relatively inexpensive method that did not require hull penetration, this mounting option was used for the 55' ANB, the 65' WYTL, and the 180' WLB (Figure 5-5).

The hydrophone swing-arm assembly was based on the manufacturer's (Ferranti-ORE) suggested design. Relatively few modifications were required for adapting to any of the three vessels. For the 180' WLB, once the material and plans were provided, two DC Petty Officers from Ship's force fabricated and installed the swing-arm mount in less than 1.5 days. In Appendix C is a sketch drawing and brief description of what was involved to fabricate the assembly.

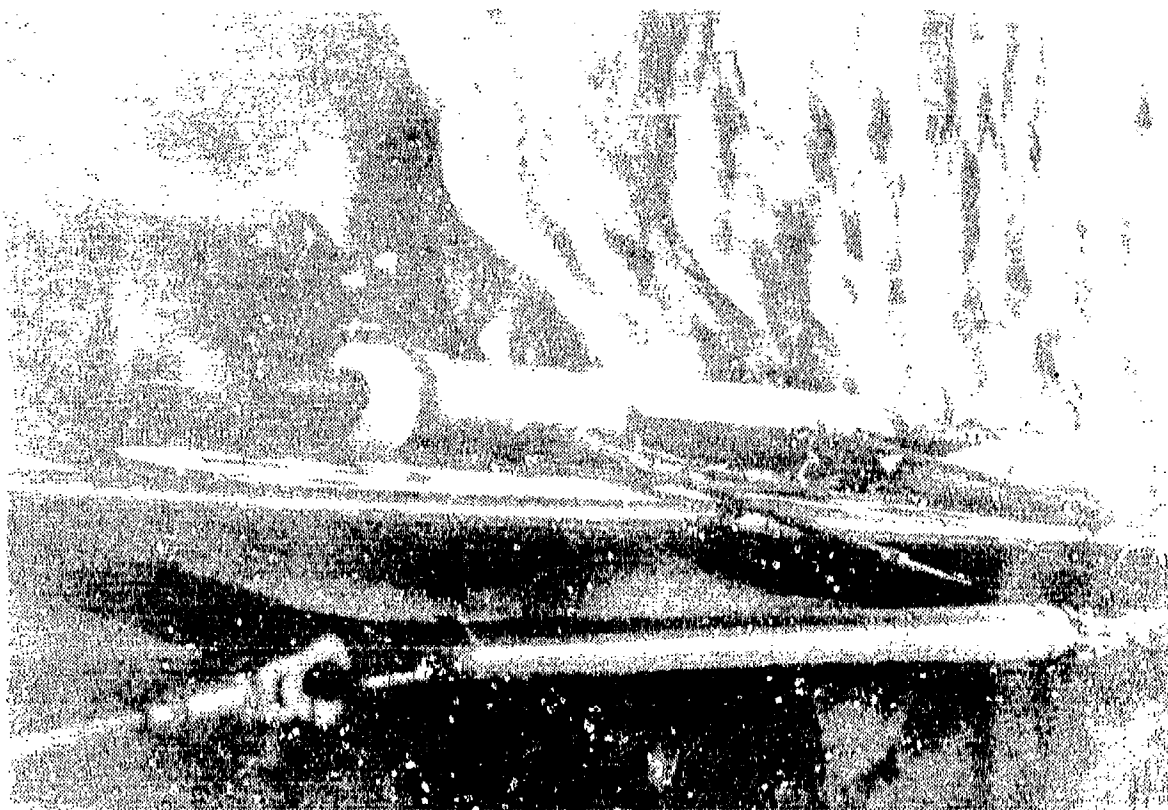


Figure 5-5. TRACKPOINT II Hydrophone Swing-arm Mounted on Starboard Side of a 65' WYTL

While in transit, the hydrophone pole is swung up and out of the water (Figure 5-6). A small block was rigged forward of the buoy port and a line was led from the lower section of the pole through the block to the port cross deck winch for hauling up. Once the sonar towing operations commence, the pole is lowered. Tension cables were fastened fore and aft, and a locking pin is placed through the pivot arm and sleeve to secure the pole in the down position.

Onboard the 65' WYTL and 55' ANB, the swing-arm design described in Appendix C worked very well under all at-sea conditions. It provided a secure mount for the hydrophone and a clear acoustic path to the towfish. The deployed swing-arm and pole also withstood considerable pitching and rolling as well as underway speeds in excess of 15 kts. However, onboard the 180' WLB the pole assembly was subjected to higher lateral

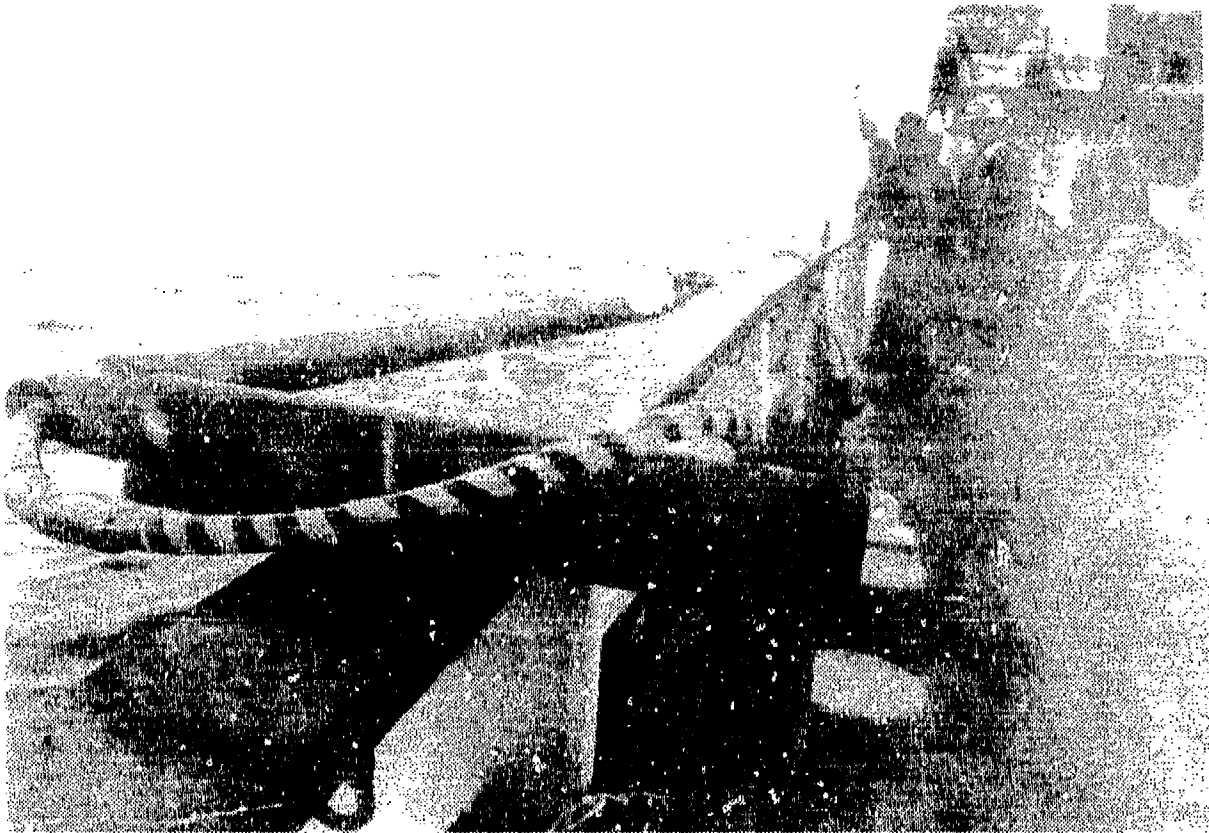


Figure 5-6. TRACKPOINT II Hydrophone Swing-arm Mounted on Port Side of a 180' WLB

loads than expected during sea-state 4 conditions and the pole deformed. If a swing-arm assembly for the hydrophone is to be employed onboard a 180' WLB, 4" schedule 80 pipe and 2" angle iron should be used.

5.2 Shipboard Installation

The IRSS was installed onboard three different classes of USCG vessels:

- o 65' Small Harbor Tug (WYTL)
- o 55' Aids to Navigation Boat (ANB)
- o 180' Seagoing Buoy Tender (WLB)

5.2.1 65' WYTL

The IRSS suite of equipment was installed onboard the USCGC BOLLARD (WYTL 65614) during 13-14 September 1988. Homeported at USCG Group Long Island Sound, New Haven, Connecticut, the USCGC BOLLARD was berthed at USCG Station New London during its participation in this project (Figure 5-7). With the assistance of 3-4 personnel from Ship's force, three technicians were able to install all equipment, including the hydrophone swing arm, during one work day.

In order for a 65' WYTL class vessel to accommodate the equipment suite, the mess deck table was removed. In its place, two standard 19" equipment racks (21" x 24" x 66") were attached to the deck utilizing the mounting bolts that normally fasten the mess deck table. With the exception of the 19" video display console (CRT) for the TRACOR TSP, the SPERRY SR-50 Gyrocompass, and the QUILS II helm display console in the pilot house, all interior ship components were installed utilizing the two equipment racks (Figure 5-1). Although the IRSS did occupy much of the vessel's mess deck, access from the pilothouse and to the lower deck berthing compartments was not severely restricted.

The TRACKPOINT II acoustic tracker hydrophone swing-arm assembly was spot-welded to the starboard side. Telemetry cables from the side scan sonar towfish and the acoustic tracker were routed to the interior of the vessel through the rear window of the pilot house. A Plexiglass window with a 4" drilled hole was used in place of the normal

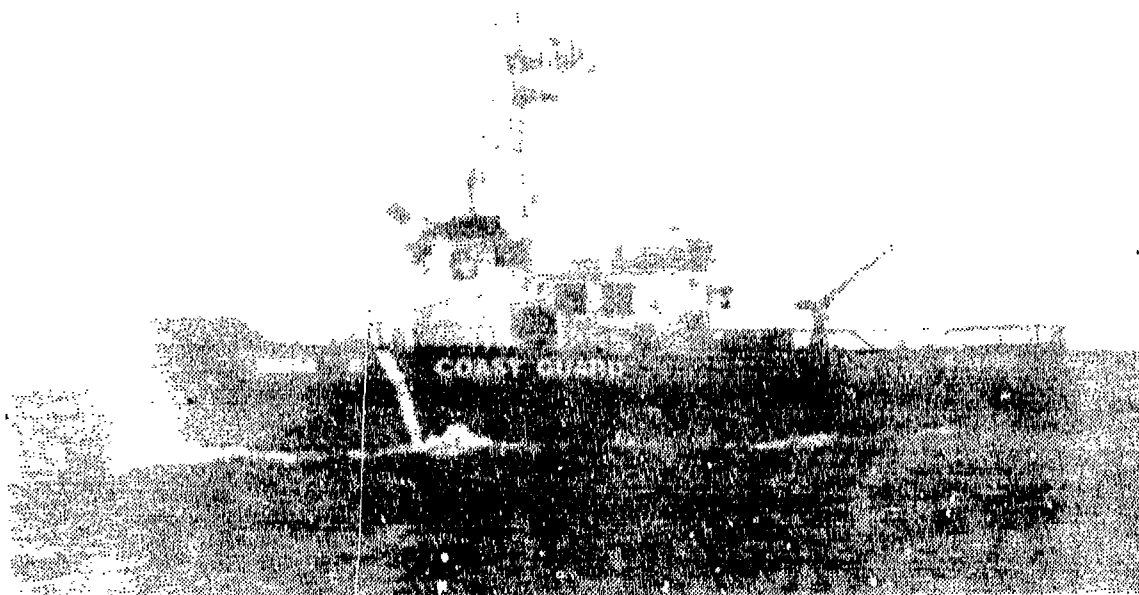


Figure 5-7. USCGC BOLLARD (WYTL 65614)

glass window pane. In this manner, the water-tight doors leading from the mess deck and the pilothouse could be closed normally.

5.2.2 55' ANB

The IRSS equipment suite was transferred from the USCGC BOLLARD and installed onboard USCG ANB 55103 on 7 October 1988 (Figure 5-8). This 55' Aids to Navigation Boat (ANB) is homeported at the Aids to Navigation Team facility at Bristol, Rhode Island. Compared to a 65' WYTL, a number of factors contributed to a somewhat shorter time period being required to load and install the IRSS equipment suite onboard a 55' ANB:

- 1) availability of a deck crane
- 2) ample main deck space
- 3) a 4'x4' deck hatch to a below deck workshop
- 4) relatively spacious workshop area

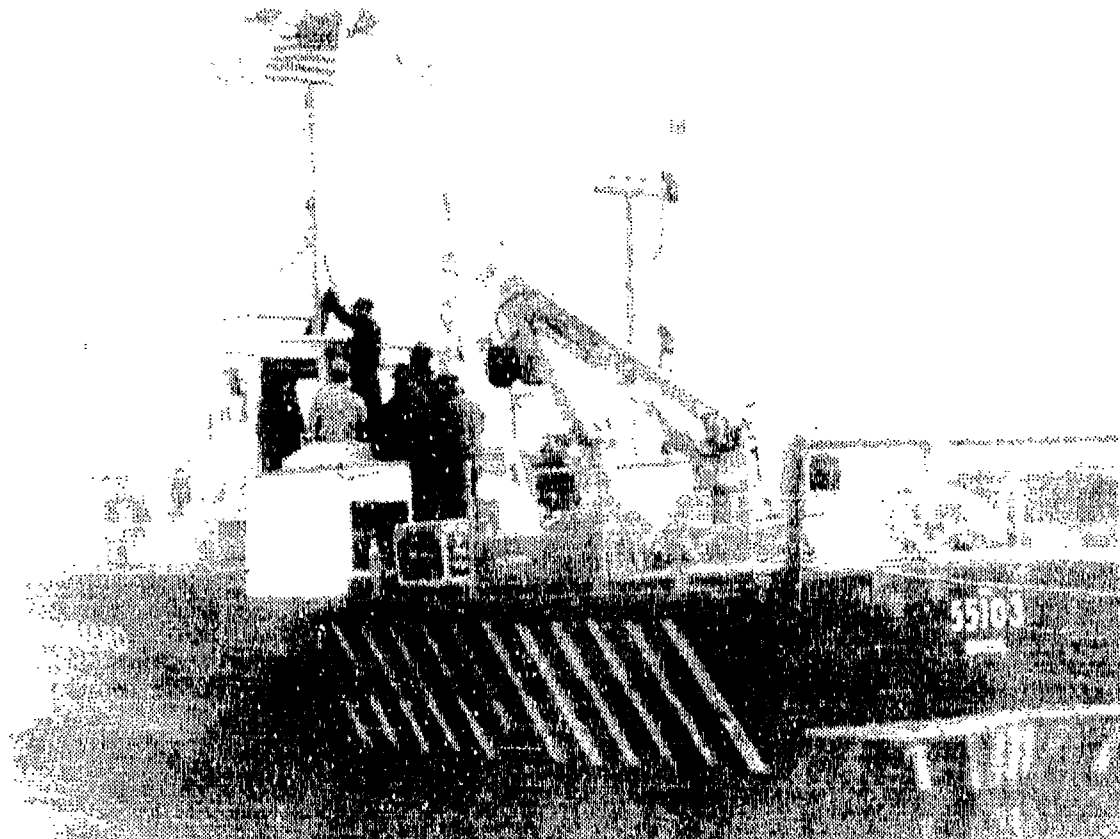


Figure 5-8. 55' Aids to Navigation Boat (ANB 55103)

The IRSS equipment suite that was installed onboard the 55' ANB was virtually identical in layout to that installed onboard the 65' WYTL (Figure 5-1). The acoustic tracker swing-arm was mounted to the starboard side similar to that for the 65' WYTL. However, rather than being spot welded to the hull, it could be bolted to the wooden deck.

For both the 65' WYTL and the 55' ANB, the underway deployment of the IRSS was similar (Figure 5-9).

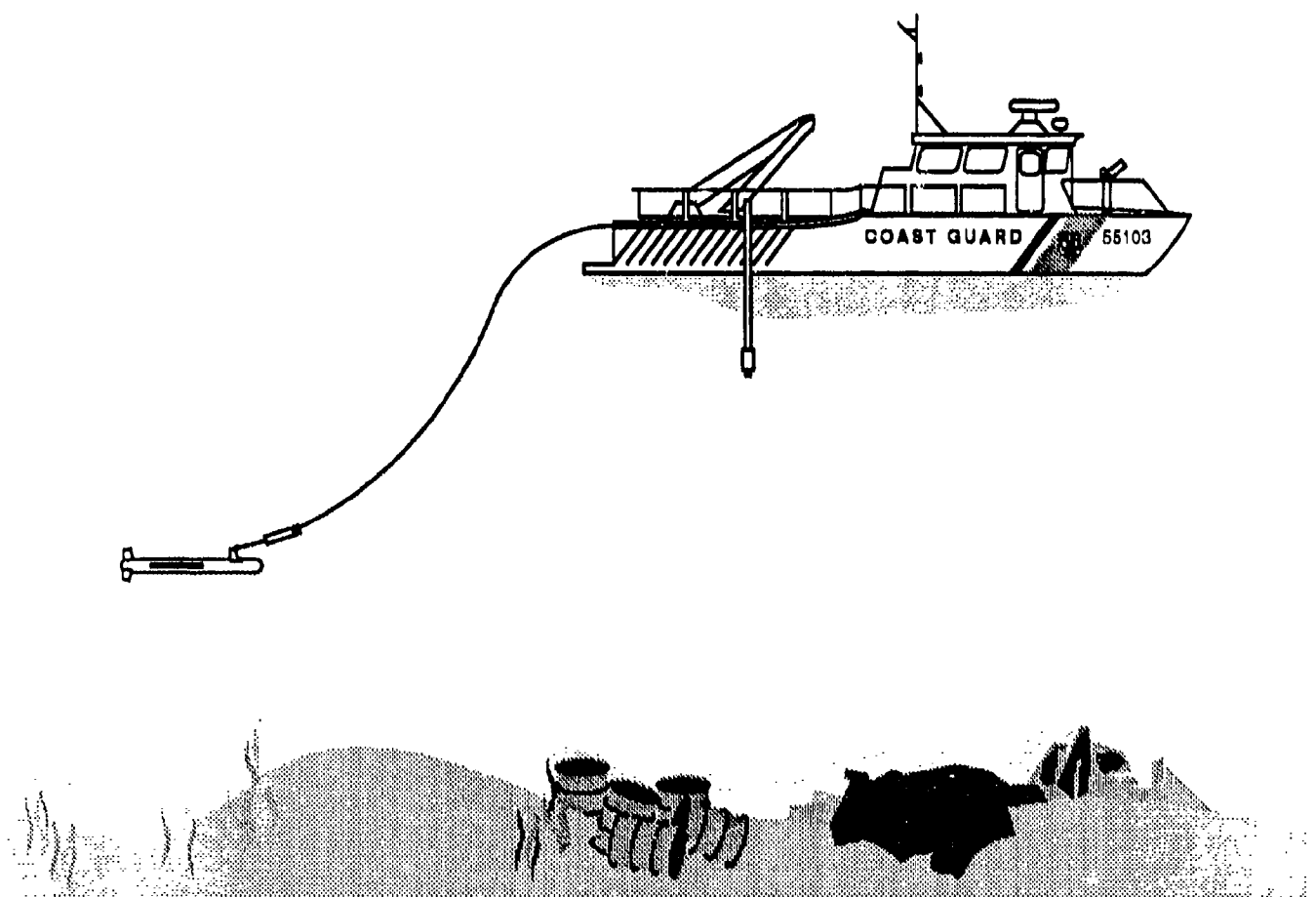


Figure 5-9. Integrated Route Survey System (IRSS) deployed from a 55' ANB

5.2.3 180' WLB

A slightly modified IRSS was installed onboard the USCGC BITTERSWEET (WLB 389) 30 April - 5 May 1989 (Figure 5-10). Evaluating the installation of an IRSS onboard a 180' WLB was a follow-on objective of the Select Project. Tests conducted by Commander, Mine Warfare Command in 1986 had shown a 180' WLB to be an "excellent platform from which to conduct route survey operations" (Ref. 2). However, that test did not address onboard space requirements necessary to accommodate an integrated Q-route survey system suite of equipment onboard a 180' WLB class vessel.

With the exception of the helm display that was installed on the ship's bridge, all of the interior ship console/recording equipment that made up the IRSS was pre-installed in a Portable Equipment Shelter at the USCG Research and Development Center prior to shipboard mobilization.

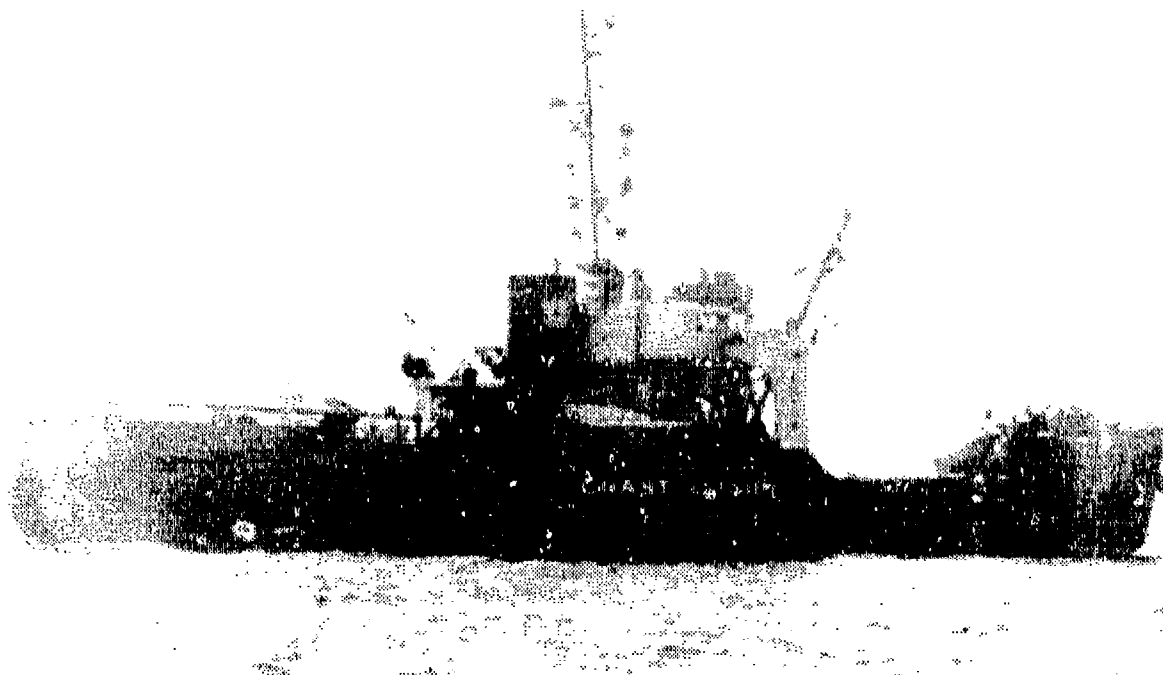


Figure 5-10. USCGC BITTERSWEET (WLB 389)

The sonar cable towing winch (described in Section 5.1.1) was hoisted on-board and mounted to the deck. In addition, the 30' pole assembly for the acoustic tracker hydrophone (Section 5.1.3) was mounted on the port side of the buoy deck.

5.2.4 Portable Equipment Shelter (PORSH)

The PORSH is a modified cargo shipping container that was originally developed as a Mobile Oceanographic Laboratory by the USCG International Ice Patrol. With dimensions of 14'x8'x8', it can be transported by trailer to a USCG vessel in support of a variety of mission requirements.

There was considerably more area and room inside the PORSH to install the IRSS suite of equipment than was available onboard the 55' ANB or 65' WYTL (Figure 5-11). Accordingly, less time was required to install and integrate IRSS into the PORSH since this process could be performed at the USCG R&D Center prior to shipboard embarkation. The functional configuration for the IRSS sub-systems and equipment installed in the PORSH was basically the same to that for the 55' ANB and 65' WYTL (Figure 5-12).

The PORSH was transported to/from the R&D Center to USCGC BITTERSWEET at USCG Group Woods Hole via a flat-bed trailer. Upon arrival, the PORSH was lifted onboard the buoy deck using the 180' WLB's main derrick (Figure 5-13). The structure was then mounted to the starboard side of the buoy deck using four (4) standard container lockdown "mushroom feet." These "feet" are 18" x 18", 1/2 inch thick steep plates that were welded directly to the vessel's deck. Additional tie-downs, consisting of a chain/turnbuckle device, were used as a further safety precaution. Total time for the PORSH to be loaded and lashed down to the buoy deck was less than one hour from time of arrival at the pier.

5.3 Installation Time

The approximate amount of time (work-hours) required for three technicians working with ship's force to install the IRSS onboard each vessel is listed in Table 5-1. These times are somewhat conservative and are listed only for comparison purposes.

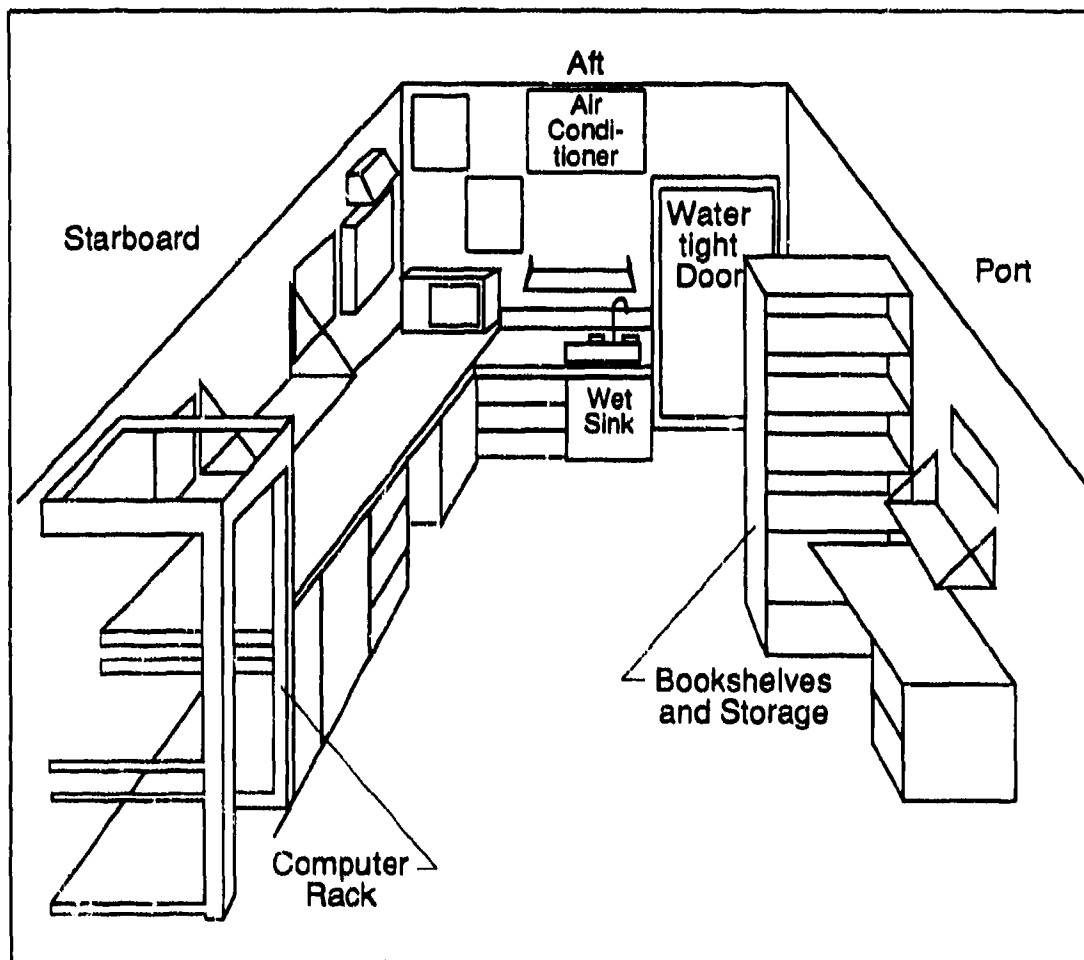


Figure 5-11. View of PORSH from the Forward End

IRSS Equipment Installed in PORSH (starboard side)

1. Sonar Receiver / Graphic Recorder
2. Video Processor / Controller
3. Sonar Video Display
4. Data Management System
5. Keyboard with Cursor ball
6. Color Console
7. Central Processor
8. Plotter
9. Printer
10. Tape Drive/Hard Drive
11. Acoustic Tracker

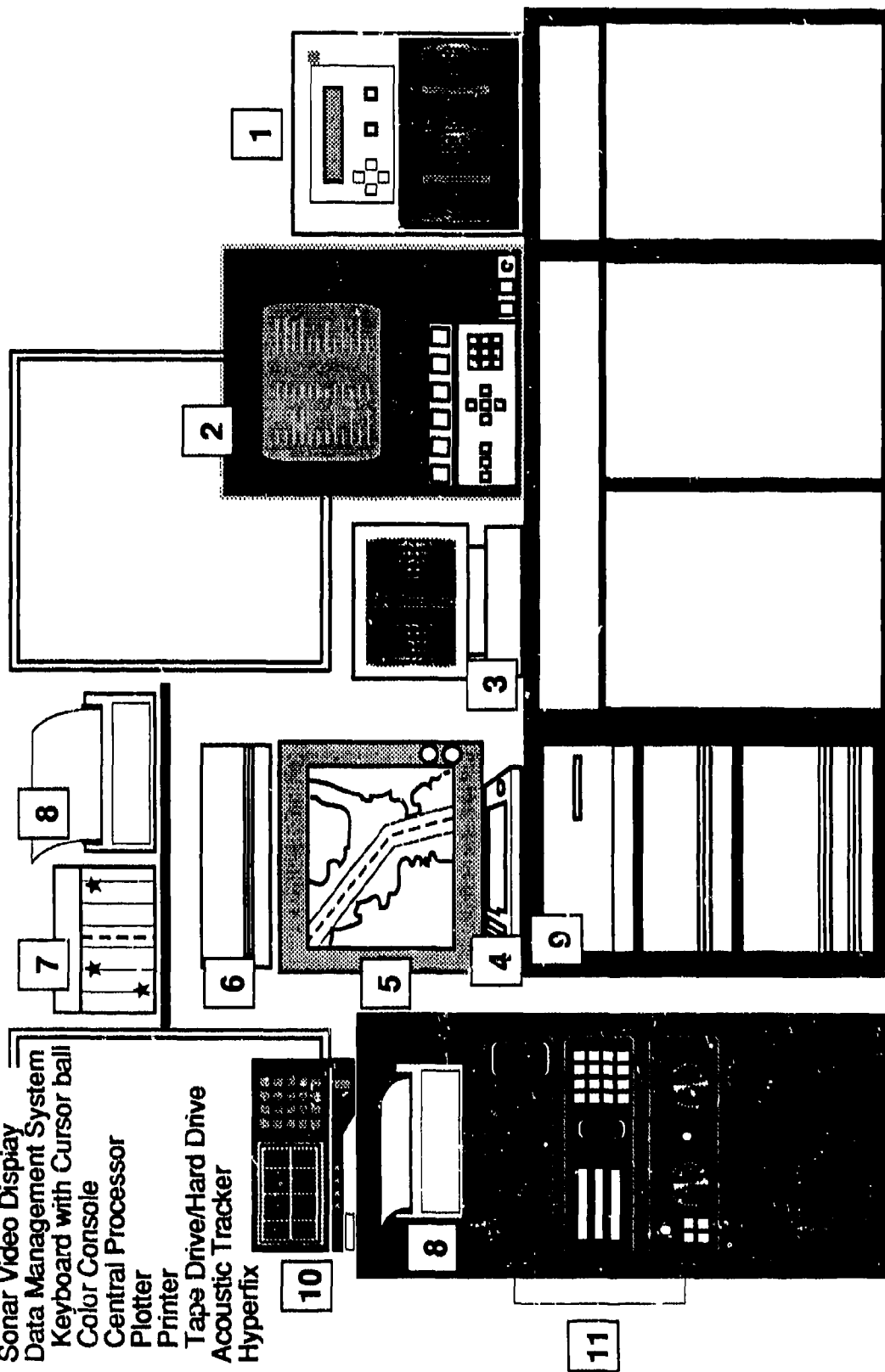


Figure 5-12. IRSS Equipment Installed in Portable Equipment Shelter (PORSH)



Figure 5-13. The Portable Equipment Shelter (PORSH) Evaluated Onboard a 180' WLB

6. TEST RESULTS

At-sea operations utilizing the Integrated Route Survey System (IRSS) installed onboard a 55' ANB and a 65' WYTL were conducted during 32 separate underway periods from September - November 1988 in New London, Connecticut. Following an initial one-week period of system checkout and familiarization in Fisher's Island Sound, all Q-route survey operations were conducted in the designated New London Q-route.

TABLE 5-1

**INSTALLATION TIMES (WORK HOURS) FOR IRSS BY VESSEL UTILIZING A
3-PERSON INSTALLATION TEAM WORKING WITH
4 PERSONS FROM SHIP'S FORCE**

<u>Equipment/Sub-system</u>	<u>65'WYTL</u>	<u>55'ANB</u>	<u>180'WLB</u>
Sidescan Sonar (KLEIN 595)			
Recorder	2.0	1.0	-
Video display console	2.0	2.0	-
Towfish & towcable	1.0	1.0	1.5
Towing winch	-	-	5.0
Display/Data Management (QUILS II)			
CPU, console, tape drive	3.0	2.0	-
Helm display	1.0	1.0	1.0
Radio Navigation/positioning			
ACCUFIX 500 (Loran-C)	1.0	1.0	0.75
Magnavox MX-4400 (GPS)	1.0	1.0	0.75
Sperry SR-50 Gyrocompass	6.0	4.0	-
Acoustic Tracker (TRACKPOINT II)			
Hydrophone swing arm	4.0	4.0	4.0
Control Console	2.0	1.0	-
Telemetry cable	1.0	1.0	1.0
Portable Equipment Shelter (PORSH)	-	-	2.0
Hours	24.0	19.0	16.0

Notes:

- 65' WYTL** All equipment had to be hand-carried onboard. For rack-mounted equipment, the racks had to be installed first.
- 55' ANB** Approximately 50% of the rack-mounted equipment could be pre-installed into the racks prior to loading and installation onboard the vessel. Utilizing the deck crane, the racks and equipment were moved from the pier and lowered to the below deck workshop through the deck hatch.
- 180' WLB** Excluding the towing winch and the hydrophone pole, most equipment was pre-installed in the PORSH prior to embarkation. The total of two hours to install the PORSH includes time required for a power supply cable/hookup from the ship.

6.1 Vessel Capability/Limitations

Both a 65' WYTL and a 55' ANB were found to be suitable vessels from which to conduct Q-route Survey operations. The suitability of a 180' WLB as a route survey platform had been established previously (ref. 2). In terms of installing or operating the IRSS, there are no significant vessel-related constraints associated with available working space, minimum vessel speed, and/or adequate electrical power. Only sea-state limitations and safe operating distance from shore are operational considerations that would preclude the use of either a 65' WYTL or a 55' ANB for Route Survey operations on a particular day or Q-route location.

Although not limiting, there are some advantages and disadvantages between the 55' ANB and the 65' WYTL when involved in route survey operations:

6.1.1 Interior Working Space

The only location that the IRSS could be installed onboard the 65' WYTL was on the vessel's messdeck. Since the messdeck table must be removed to accommodate the IRSS equipment racks, this precludes the use of the messdeck as a lounge/eating area for the crew. Onboard the 55' ANB, the IRSS can be installed in the below deck workshop. This space is not normally used while the vessel is underway and does not interfere with any other onboard operations. In addition, this space can be accessed from the fantail through a watertight door or directly from the bridge via a vertical ladder.

6.1.2 Deck Space

Both a 65' WYTL and a 55' ANB have ample main deck area on the fantail in which to launch and recover the side scan sonar towfish. The 55' ANB has a stern platform that permits a near water-level launch/recovery of the towfish. The inflatable rubber boat normally carried on the fantail of the 65' WYTL was not an obstacle. In fact, the small boat davit was used often during towfish launch/recovery procedures. The fantail of the 55' ANB was found to be a "wetter" working area than the fantail of a 65' WYTL.

6.1.3 Minimum Speed

As specified in the COMINELWARCOM Route Survey TACMEMO (Ref. 11), Q-route survey operations should be conducted at a 4 knot or less speed-over-ground

(SOG). A 65' WYTL has a single shaft and a minimum speed of 5.5 kts. However, this class of vessel has a relatively large rudder and is very stable and maneuverable at slow speeds. Although a 55' ANB has two shafts, the vessel is capable of operating at a minimum speed of 4 kts on one shaft. However, at this minimum speed the vessel is not particularly maneuverable.

In most instances, minimum vessel speed is not a limiting factor if there is any type of current present. Prudent mission planning can take into account the direction and speed of currents in that area of the Q-route to be surveyed. In terms of vessel maneuverability and SOG, heading into a current is the preferred tactic when conducting route survey operations.

6.1.4 Maximum Speed

With a maximum speed of 13 knots, the 65' WYTL requires a longer time to transit to and from an operating area than a 55' ANB which has a maximum speed in excess of 20 knots. However, as shown in Table 6-1, the observed differences between the two vessels was not great. Prudent mission planning can help to minimize in-transit time periods.

6.2 **Operational Availability**

The operational availability of IRSS when installed and operated onboard the 65' WYTL and 55' ANB was evaluated over a two-month time period. Operational availability was measured in terms of the number of times the system performed satisfactorily compared to the total number of times its performance was required. The total number "required" was based on the number of underway periods either scheduled or attempted.

As shown in Table 6-1, there was only one occasion when the IRSS was inoperative, precluding the vessel from getting underway to conduct Route Survey operations. Other factors that prevented either vessel from getting underway were related to poor weather, an engineering casualty, and the period of time required to install/remove the IRSS suite of equipment.

TABLE 6-1
OPERATIONAL AVAILABILITY OF IRSS ONBOARD A 65' WYTL AND 55' ANB

	<u>55' ANB</u>	<u>65' WYTL</u>
a) <u>Daily Operations</u>	----- Days -----	
Vessel underway	19 (75%)	16 (89%)
Inport due to:		
poor weather	2 (8%)	0
engineering casualty (vsl)	1 (4%)	0
IRSS inoperative	1 (4%)	0
system install/remove	<u>2 (8%)</u>	<u>2 (11%)</u>
TOTAL	24 days	18 days
b) <u>Activity During Underway Periods</u>	----- Hours -----	
On-task	42.00 (56%)	33.75 (60%)
Off-task *	9.25 (12%)	5.75 (10%)
In-transit	<u>24.00 (32%)</u>	<u>16.75 (30%)</u>
TOTAL	75.25 hrs	56.25 hrs

* See Table 6-2

During the underway periods, over 56% of the time was spent on-task conducting route survey operations. Despite the difference in maximum vessel speed between the 65' WYTL (13 knots) and the 55' ANB (20+ knots), the portion time spent in-transit was not significantly different. Most often, the time spent in-transit was used for mission planning, equipment setup/check-out, training of new personnel, analyzing previous effort/accomplishments, and post-mission analysis/data download. Those instances that caused either vessel to be off-task were most often due to navigation-related problems (Table 6-2).

TABLE 6-2
CAUSES OF IRSS-RELATED OFF-TASK PERIODS
DURING UNDERWAY OPERATIONS

<u>Off-Task due to:</u>	<u>no. instances</u>	
Navigation inaccuracy	10	(33%)
Acoustic tracker	6	(20%)
Navigation calibration	4	(13%)
Rough weather/seas	3	(10%)
Personnel/training	3	(10%)
Gyrocompass errors	2	(07%)
Towfish performance	<u>2</u>	(07%)
TOTAL	30	

6.3 Mission Reliability

During the two-month underway period the IRSS was operated onboard the 55' ANB and the 65' WYTL, there were 22 instances when the integrated system was not able to fully perform a detailed Q-route survey mission (Table 6-3). Seventeen (77%) of the mission degradation/failures were classified as "minor", while 4 (14%) were considered "major".

A "minor failure" was one which affected the performance of the system but did not result in a significant adverse impact. In the case of precision navigation components, if the primary system (Differential Loran-C) was not available, the secondary system (Loran-C) was relied upon.

"Major failures" were those that caused the IRSS to lose some of its operational capability, thus degrading mission accomplishment.

There was one "critical failure" of IRSS that prevented the vessel and crew from performing a Q-route survey mission (mission abort). This instance occurred onboard the 55' ANB was caused when the Lehmkuhl LR-60 gyrocompass repeater failed. Without a

TABLE 6-3
CAUSES OF IRSS-RELATED MISSION DEGRADATION/FAILURES

<u>Date</u>	<u>Vessel</u>	<u>System/component</u>	<u>Degradation/Failure</u>	<u>Impact</u>
9/19	65'	Diff Loran-C	inop receiver	minor
9/20	65'	Diff Loran-C	erratic performance	minor
9/21	65'	Trackpoint II	erratic performance	minor
9/22	65'	Diff Loran-C	RF link inop	minor
9/22	65'	Trackpoint II	transponder inop	minor
9/23	65'	Diff Loran	RF link erratic	minor
9/27	65'	Diff Loran/GPS	erratic performance	MAJOR
9/28	65'	towfish	lost tailfins	MAJOR
9/30	65'	Diff GPS	erratic performance	minor
10/12	55'	Gyro repeater	defective part	CRITICAL
10/13	55'	QUILS II monitor	lost screen focus	minor
10/13	55'	Diff Loran-C	shore sta link inop	minor
10/14	55'	towfish	lost tailfins	MAJOR
10/18	55'	Diff Loran-C	computer/software	minor
10/18	55'	Trackpoint II	transponder inop	minor
10/19	55'	Trackpoint II	erratic performance	minor
10/20	55'	towfish	fouled on lobster pot	minor
10/31	55'	Diff Loran-C	shore sta link inop	MAJOR
10/31	55'	Trackpoint II	erratic performance	minor
11/3	55'	Trackpoint II	erratic performance	minor
11/3	55'	Loran-C	Chain off-line	minor
11/4	55'	Gyro repeater	erratic performance	minor

digital signal from the gyrocompass repeater to the QUILS II central processing unit, the bridge helm display could not be operated.

6.4 System/Operator Interface

An important project objective was to evaluate the performance/capability of the IRSS when operated by personnel with a range of experience, skills, and talent. Overall, both USCG and USN personnel were quickly able to pick up on the concept and conduct of Q-route survey operations.

6.4.1 Basic Operational Procedures

To the greatest extent possible, Q-route survey operations were conducted in accordance with the basic procedures described in the COMINELWARCOM Q-route Survey TACMEMO, 1-89 (Ref. 11). However, specific guidance on procedures to use when an integrated navigation and data management system is available is limited. Listed below is the sequence of procedures that were found to be most appropriate when using IRSS.

1. Mission Setup (QUILS II)
 - Upload the historical contact database
 - Check/reset vessel and equipment parameters
 - Conduct day's mission planning (i.e., portion of Q-route to be surveyed)
2. Equipment Checkout
 - navigation sub-systems
 - Loran-C
 - GPS
 - towfish and transponder
 - side scan sonar recorder (paper roll)
 - sonar video display (cassette tape)
3. Transit to area of Q-route to be surveyed
 - review QUILS II historical contact database
 - provide target area destination (Bull's eye) on helm/bridge display

4. Lower TRACKPOINT II hydrophone
 - lower 500 yds before entering survey area
 - slow vessel to minimum speed
5. Deploy towfish
 - while on deck, confirm side scan sonar towfish signal to sonar recorder (rub test)
 - confirm that acoustic transponder is turned on
 - deploy while vessel is underway (3-5 knots) prior to entering intended track
6. Payout towcable
 - control towfish altitude by scope of towcable
 - use depressor vane if maximum scope does not achieve desirable depth (normally used for depths > 120')
 - coordinate with Klein side scan recorder operator to achieve optimum towfish altitude above seafloor (10-20 m)
7. Steer vessel along intended track
 - helmsman steers vessel utilizing the QUILS II helm display
 - helmsman needs to avoid sharp turns and rapid changes in vessel speed
8. Conduct sonar conditions check
 - use nav aid, previous/historical contact, or sonar reflector
9. Mark and designate (classify) sonar contacts
 - annotate with pen on the side scan sonar recorder
 - mark and measure dimensions of contact with video display
10. Monitor performance of IRSS
 - primary and secondary nav systems
11. Recover towfish
 - "walk-around" method (vs hand-over-hand) most effective recovery method
 - fake down towcable onto deck in "figure 8".

12. Recover TRACKPOINT II hydrophone pole
 - back vessel down; pole swings forward easily
13. Post-mission data download/record compilation
 - perform during return transit to port

6.4.2 Personnel

A variety of USN and USCG officer and enlisted personnel were utilized to operate the various IRSS system components during underway operations (Table 6-4). In general,

TABLE 6-4

USCG AND USN PERSONNEL INVOLVED IN THE OPERATION OF IRSS

USCG

Helm Display/Indicator	1 Petty Officer (Coxswain)
Fantail Operations	1 Petty Officer (Supervisor)
	3 enlisted personnel
Navigation receivers	1 Petty Officer

USN

QUILS II Console	1 Petty Officer
Sonar recorder/video display	1 Petty Officer
Officer-in-Charge	1 LT/LTJG (USCGR/USNR)

USCG personnel were responsible for the deployment/recovery of the side scan sonar towfish and acoustic tracker hydrophone, the operation of the precision navigation receivers, and use of the helm display to pilot the vessel. U.S. Navy enlisted personnel were assigned the operation of the tactical display/data management console (QUILS II), and for operating the side scan sonar recorder/video display. For the majority of the underway periods, a Naval Officer was assigned to supervise the overall Q-route Survey operation.

6.4.3 Training

U.S. Coast Guard crews on each vessel required only a brief initial familiarization and training period in order to be able to effectively deploy and recover the side scan sonar towfish and hydrophone pole (Figure 6-1 a-d). Likewise, the purpose and operation of the helm/steering display was quickly learned. Once the basic concept was explained and demonstrated, detailed instruction on how to use the helm display was not required.

With only two days of pierside/at-sea training, USN enlisted operators were able to effectively operate the QUILS II console and the sonar recorder/video display equipment (Figure 6-2). Less time was needed if they had some previous MCM/mine hunting or Q-route Survey experience. However, during all underway periods, a qualified systems engineer was always available to provide assistance or supervision.

Technical manuals were available for each sub-system, equipment, or component. However, they were not referred to very often. When used at all, it was for trouble-shooting a problem. The TRACKPOINT II and the Tracor TSP manuals were consulted most often, the QUILS II the least. The QUILS II had a particularly useful on-screen "Help function" in which various levels of information could be displayed.

At least two weeks of intensive training is probably the minimum period that would be required in order for a person to become reasonably proficient in overall IRSS installation, operation, trouble shooting, and maintenance. However, this level of training would probably not be sufficient for a person to become experienced in all aspects of Route Survey operations as it relates to tactical planning, deployment/recovery operations, and post-mission data analysis.

6.4.4 Safety

There were no documented instances of significant safety hazards occurring during the two months of route survey operations. Nor were any major safety hazards observed that were associated with installation and use of IRSS onboard any of the vessels. All main deck operations onboard the 65' WYTL and the 55' ANB were supervised by the vessel's leading Petty Officer (BMC) and by the USNR Officer-in-Charge of the Route Survey Operation. Prudent seamanship and "safety first" shipboard operations precluded most potentially dangerous situations from occurring.

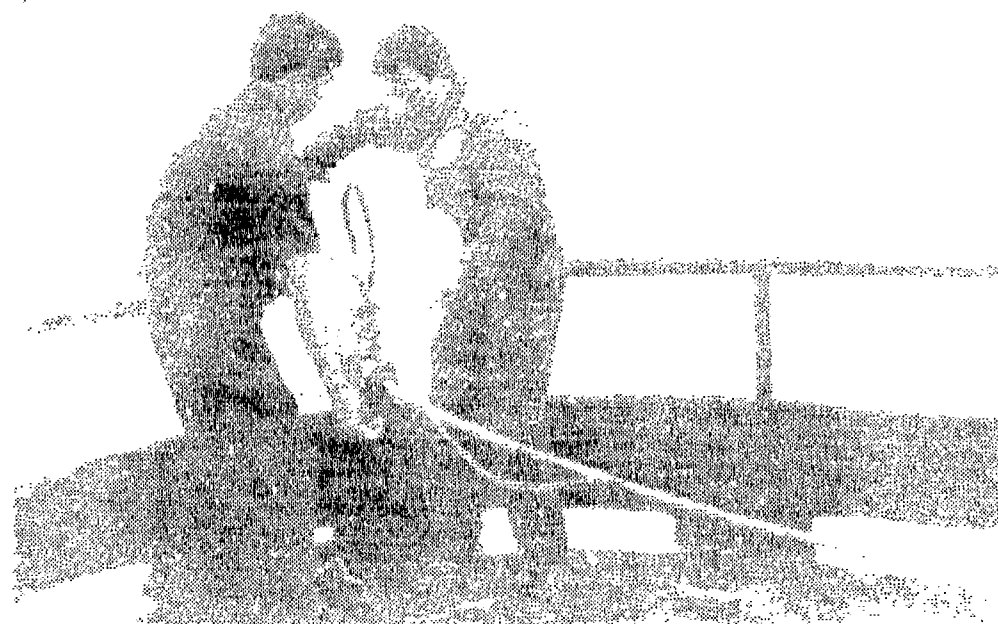
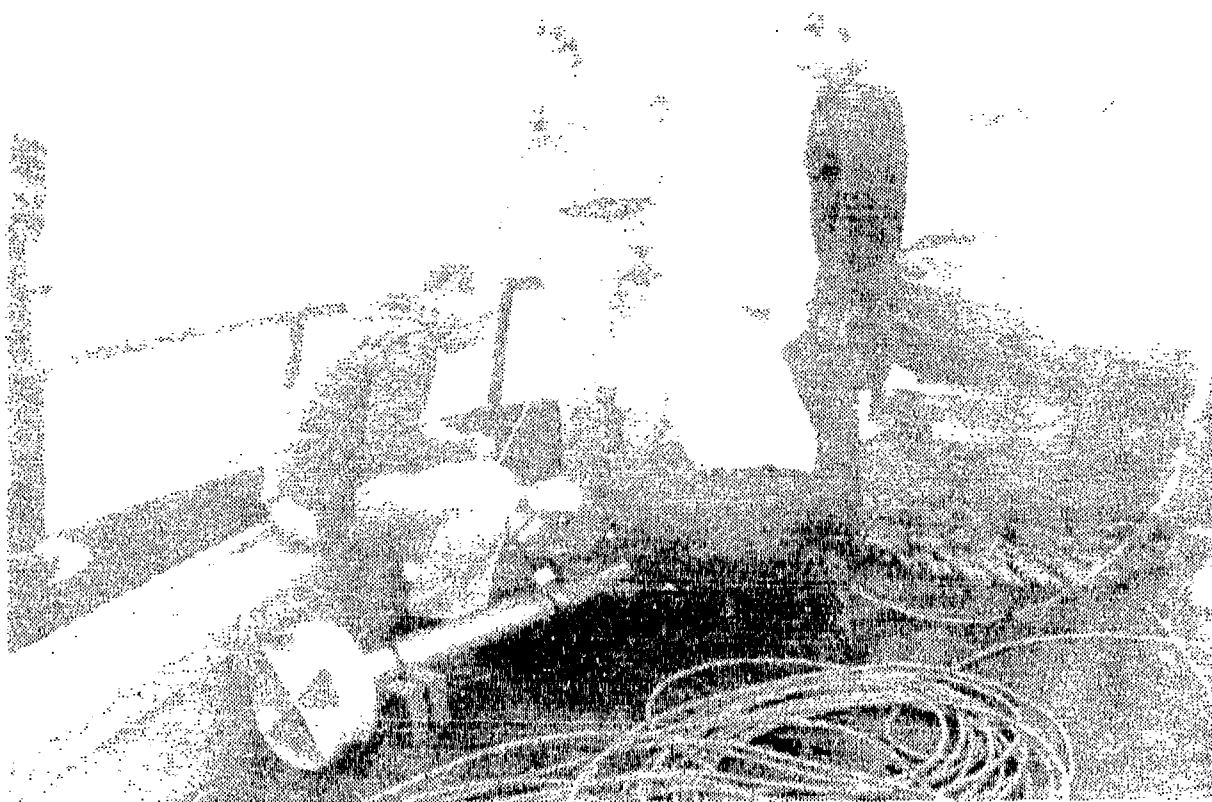


Figure 6-1 a & b. Side Scan Sonar Towfish Launch and Recover Operations

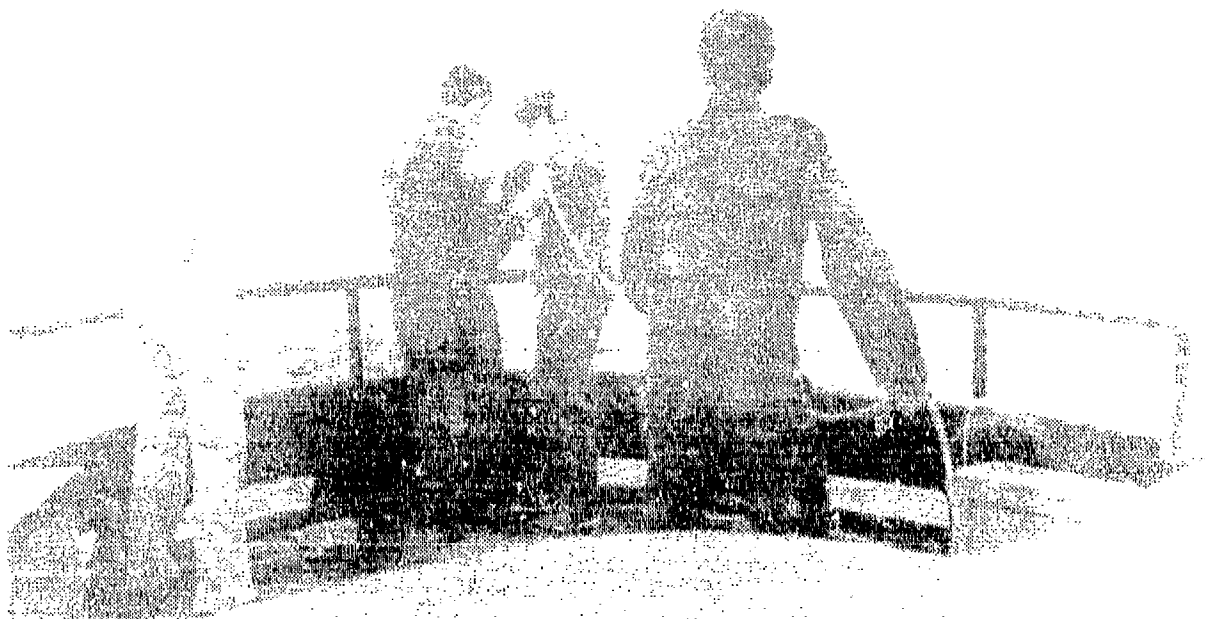


Figure 6-1 c & d. Side Scan Sonar Towfish Launch and Recover Operations



Figure 6-2. USN Personnel Operating the IRSS Onboard a USCG 55' ANB

Visible surface hazards in the form of buoys (navigation aids, fishing) and floating debris were easily avoided. However, sub-surface obstructions (e.g., lobster trap lines, fishing nets, etc.) that could not be seen were occasionally snagged by the towfish. Normally, it was not a difficult operation to become dis-entangled. On two occasions, the tailfins of the towfish were sheared.

Interference from other surface vessels while conducting Q-route survey operations was not found to be a problem. When the Route Survey vessel was on-task, appropriate day shapes for "special operations" were shown. Bridge-to-bridge communications between the Q-route survey platform and other vessels in the immediate area were seldom required.

6.4.5 Coordination and Communications

Effective route survey operations required considerable coordination and verbal communication between the on-deck launch/recovery team, equipment console operators, and the pilothouse. Voice communications without the assistance of sound-powered phones or hand-held radio sets were not always adequate. In addition to coordinating the launch/recovery of the towfish and hydrophone, effective communications were also required to achieve the necessary altitude of the sonar towfish when encountering changing depths or currents.

While unassisted voice communications were usually adequate onboard the 55' ANB and 65' WYTL, sound-powered phones or hand-held radio communications sets become more crucial when operating onboard a large vessel such as a 180' WLB. Onboard the 180' WLB, inadequate communications between the PORSH, the pilot house, and the fantail (where the side scan sonar towing winch was located) was a contributing factor in the loss of a towfish when the winch drum failed to hold.

6.4.6 User-Friendliness

In an effort to objectively assess IRSS user-friendliness (man-machine interface), USCG and USN personnel were asked to comment at the end of each day's underway route survey operation. A detailed questionnaire was also completed by each USN enlisted operator and the Officer-in-Charge at the completion of his/her participation in the project, (Appendix C, Data Sheet C).

By design, the various components/sub-systems are all intended to be user-friendly. Despite little or no formal training, most operators were able to quickly learn how to operate the various system components. None of the major display consoles required a keyboard to operate:

<u>Console</u>		<u>Man-machine interface</u>
helm display/indicator	-	key pad
sonar video display	-	touch screen
QUILS II	-	roller-ball cursor

Most operators were able to easily select and operate the various functions. When asked to rate the relative ease of operation of the various sub-systems/equipment components:

<u>Relative Ease of Operation:</u>	<u>Difficulty</u>
Trackpoint II console	most
TRACOR TSP/Q-MIPS display	
QUILS II Console	
Side scan sonar recorder	
LORAN receiver	
Helm Display/indicator	least

Several operators remarked that when the IRSS was fully functional, the consoles were no more difficult to operate than a "video game" or a home VCR. Those instances when operators experienced difficulty primarily occurred when the navigation/positioning system was not performing well. In these cases, the cause of the problem (i.e., operator error versus system malfunction) was not always apparent.

6.4.7 Vessel Piloting

Onboard all USCG vessels the helmsmen/coxswain quickly learned to use the helm display for piloting the vessel along an "intended" (pre-determined) track (Figure 6-3). After less than two hours on-the-job training, most were able to maintain the vessel within 20 yards of intended track more than 50% of the time. The only factor encountered that

made it difficult for a helmsman to steer/maintain a vessel along an intended track were large swells on the stern quarter. These swells would lift the stern of the vessel, causing it to swing off-course. Cross currents and wind or swells on the beam were usually not a problem.



Figure 6-3. QUI S II Helm Display/Indicator Installed Onboard USCGC BITTERSWEET (WLB 389)

Figure 6-4 is a cumulative distribution plot of the number of meters left/right of intended track for the three classes of vessels that were evaluated. These data were collected over a series of on-task time periods when Differential GPS was available and could be used as a ground truth navigation/positioning system.

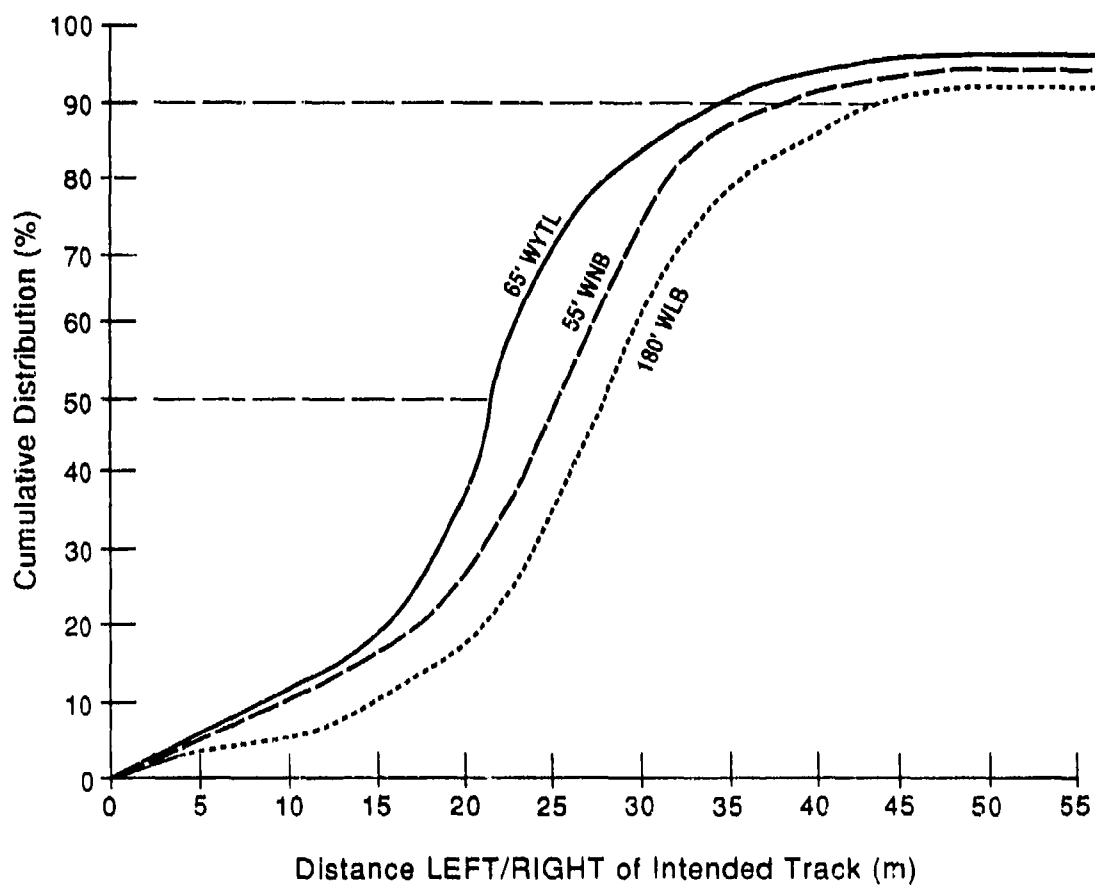


Figure 6-4. Distance of USCG Vessels Left/Right of Intended Track When Conducting Q-route Survey Operations

All three vessels were within 30 yards of intended track 50% of the time, and within 45 yards 90% of the time. Although not specified in the Route Survey TACMEMO, this degree of vessel piloting/positioning accuracy (track-made-good versus intended track) should be more than adequate when track-line spacing/overlap becomes crucial. As a Q-route Survey platform, a 65' WYTL was slightly better able to be piloted closest to intended track when using the IRSS (QUILS II helm display/indicator). However, the differences in range between the observed piloting capability of the three vessels when conducting Route Survey operations with the IRSS was less than 15 meters.

6.5 Operational Suitability

During the conduct of the Q-route Survey Demonstration Project (September - November 1988) a 30 mile portion of the New London Q-route was surveyed. A wide range of bottom types/topography, depths, currents, and sea-state conditions were encountered. Since the primary focus of the project was an overall operational assessment of systems and procedures, no controlled testing was performed to determine probability of detection (POD) or effective sweep width ranges for various sized objects that could be detected and located on the seafloor. However, observations made during the two months of underway operations confirmed that there are a number of parameters that contribute to the effective conduct and accomplishment of route survey operations. In decreasing order of importance they are:

- 1) Performance of the precision radio navigation system (reliability, repeatability, and/or accuracy)
- 2) Side scan Sonar procedures/tactics:
 - a. operating frequency (100 kHz or 500 kHz)
 - b. range setting
 - c. altitude of the sonar towfish above the seafloor
 - d. speed of the towfish (speed over ground)
 - e. topography/composition of the seafloor
- 3) Sea-state/environmental conditions

6.5.1 Precision Navigation

The most critical factor that determines the effectiveness of route survey operations is the availability and performance of a precision radio navigation system. Although a certain level of repeatability or geodetic accuracy is necessary in order to be able to determine the "true" location of any contact detected, a navigation system that is unreliable or periodically unavailable will significantly degrade a route survey operation. If, during the conduct of the Q-route survey operation, the position of either the survey vessel or the towfish is never accurately determined or recorded, the side scan sonar route survey data collected is of limited value.

Racal Decca HYPERFIX

One of the original objectives of the New London Q-route Survey Demonstration Project was to conduct a simultaneous evaluation of the suitability and effectiveness of Loran-C, Differential Loran-C, and HYPERFIX when used during route survey operations. For several reasons, this objective could not be accomplished.

The portion of the New London Q-route that was surveyed during September - November 1988, did not have HYPERFIX coverage.

In the spring of 1989, the USCG R & D Center assisted personnel from Naval Weapons Support Center (NWSC) Crane, Indiana, in establishing additional HYPERFIX transmitter sites necessary to provide full coverage. However, the two transmitter sites (Watch Hill, Rhode Island and Millstone Point, Niantic, Connecticut) were not surveyed in time for the 1-4 May 1989 underway period onboard the USCGC BITTERSWEET. Although the net was functional, the reconfigured chain was not fully operational in that it had not been re-calibrated and could not provide accurate geodetic positioning.

The installation and operation of HYPERFIX onboard the USCGC BITTERSWEET was performed by personnel from NWSC Crane and an engineer from Racal-Decca, Sussex, England, UK. Originally, it was intended that the HYPERFIX positioning solutions provided to QUILS II would be monitored and evaluated during those periods when four-satellite GPS coverage was available. However, the computer that performed the simultaneous data collection and comparison of HYPERFIX to DGPS

(truth position) assigned erroneous "time tags" to the data stream. Post-mission efforts to reconstruct the time tag sequencing so that accurate comparisons could be performed were not successful.

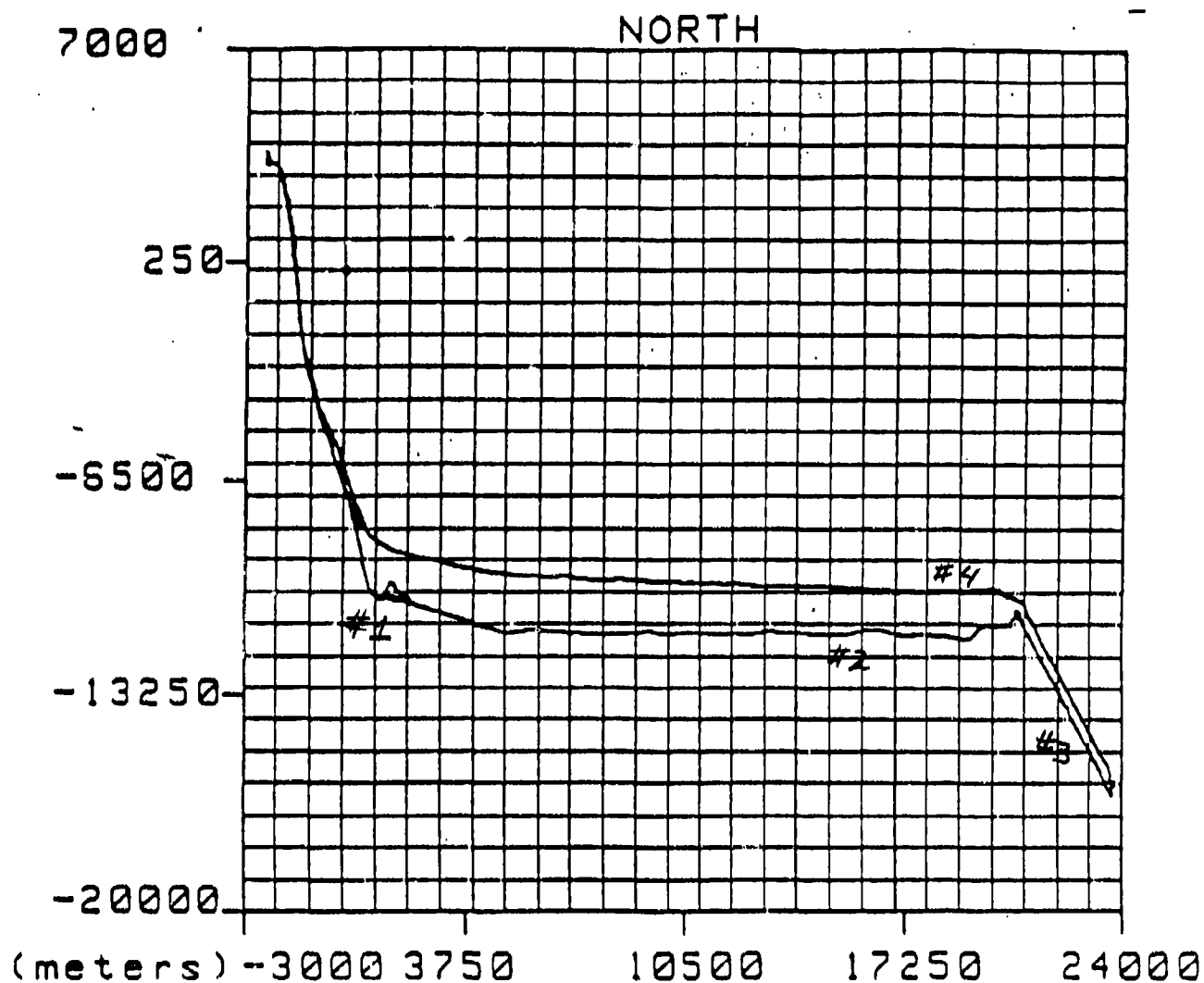
Currently, there are no plans for the USCG to acquire HYPERFIX or for the Navy to provide it to the USCG when performing a Q-route survey mission under the MARDEZ concept of operations.

Differential Loran-C

In the portion of the New London Q-route that was surveyed during September - November 1988, the USCG R&D Center installed and operated a temporary Differential LORAN-C (DLC) and Differential GPS (DGPS) network as alternative precision navigation systems to Racal-Decca HYPERFIX. Since DLC and DGPS were prototype systems, both were installed and operated by engineers and technicians from the USCG Research and Development Center. For this reason, an evaluation of the operational suitability and effectiveness of the two precision navigation systems when operated by personnel likely to be involved in Q-route Survey operations could not be conducted. However it is expected that fully operational versions of these systems would require operator skills consistent with the other components of IRSS.

In order to evaluate the performance of DLC during underway periods, two Differential GPS (DGPS) receivers were used by USCG R & D Center engineers as "truth positioning" system. In this manner, the position derived when using DLC could be compared to that of DGPS. The capability of DGPS to serve as a "truth positioning" system for at-sea evaluations is discussed in Ref. (12).

Figure 6-5 shows a trackline plot of the Q-route survey operations conducted in Long Island Sound and Block Island Sound on 20 October 1988. Since the location of the Q-route is classified, land features and geographic coordinates are not shown in the figure. The plot indicates the entire track of the survey vessel during that day's operations, and includes both on-task and off-task time periods. During the underway period, there was 4-satellite GPS coverage from 0930-1415. Using two GPS receivers in a Differential mode, a DGPS position solution was used as a reference position for evaluating the performance of DLC. During the day's operation, environmental conditions were nearly ideal. Winds were light and there was little chop or swell.



		<u>Weax</u>	<u>Sea State</u>	<u>Y SOG (kts.)</u>
#1	First leg	Clr, Calm	1	3.8
#2	Second leg	Clr, Calm	1	4.6
#3	Third leg	Clr, Calm	1	4.1
#4	Fourth leg	Clr, Calm	1	3.3

Figure 6-5

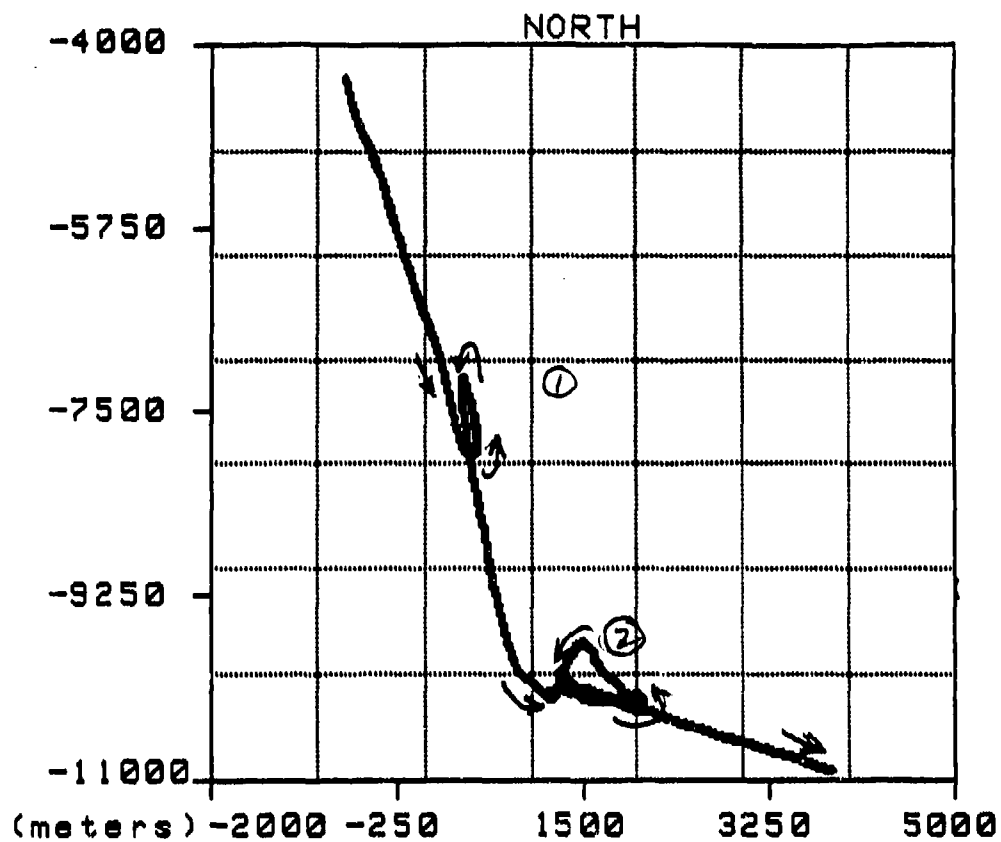
Survey vessel trackline plot of Q-route survey operations conducted on 20 October 1988 during New London Q-route Survey Demonstration Project

During the on-task time periods, four separate sections (legs) of the Q-route were surveyed. Figure 6-6 is a trackline plot of the survey vessel during the first leg of the Q-route survey operation. Two events warrant comment. Event #1 shows the trackline of the vessel when it conducted a side scan sonar validation check and navigation verification of a known object at a known geographic location. Event #2 shows the trackline of the vessel before and after the side scan sonar towfish snagged a lobster trap line. In this situation, the vessel stopped to retrieve the towfish and then re-acquired the previous survey trackline near the location where the towfish became fouled. During the time period required to conduct this leg of the Q-route survey, 79% of the positions derived by DLC were within 20m of the reference positions established by DGPS (Figure 6-7a & b), or 27 meters, 2 DRMS.

The trackline plot for the second leg (Figure 6-8) shows a situation where the survey vessel purposely altered course (Event #3) in an effort to detect an historical sonar contact that had been located during previous Q-route survey operations. In order to return to the location of this "historical contact," a predictable, geodetic accuracy of 20m or less is considered necessary for effective re-acquisition and verification (Ref. 11). As shown in Figure 6-9a & b, 82% of the DLC positioning solutions during this evolution were within 20m of the DGPS reference positions or 26 meters, 2 DRMS.

Figure 6-10 shows a trackplot of Q-route survey operations conducted at some distance from the coastline. The location of Event #4 was the farthest from shore location in which Q-route survey operations were conducted during the September-November 1988 trials. As indicated by the scatter plot and cumulative distribution curve (Figure 6-11a & b), the positioning accuracy of DLC was better at this location than for the near-shore portions of the Q-route, (18 meters, 2 DRMS). This improvement in positioning is most likely the result of less over land interference of the Loran-C signal from the Master and/or Secondary transmitter stations.

The fourth (last) leg of the Q-route survey operations conducted on 20 October 1988 was in the vicinity of the second leg that had been surveyed earlier in the day (Figure 6-12). As shown by Figure 6-13, the precision of the DLC positioning solution was less than that achieved farther from shore. However, the positioning accuracy of DLC was comparable to that achieved in this general vicinity two hours earlier.



20 October 1988
1002 - 1104R

Event No.

- | | |
|---|------------------------------------|
| 1 | Sonar validation check |
| 2 | Towfish snagged a lobster pot line |

Figure 6-6. Trackline Plot of Route Survey Leg #1

2599 measurements

$\leq 8\text{m} = 7.2\%$

$\leq 20\text{m} = 72.0\%$

$> 20\text{m} = 20.9\%$

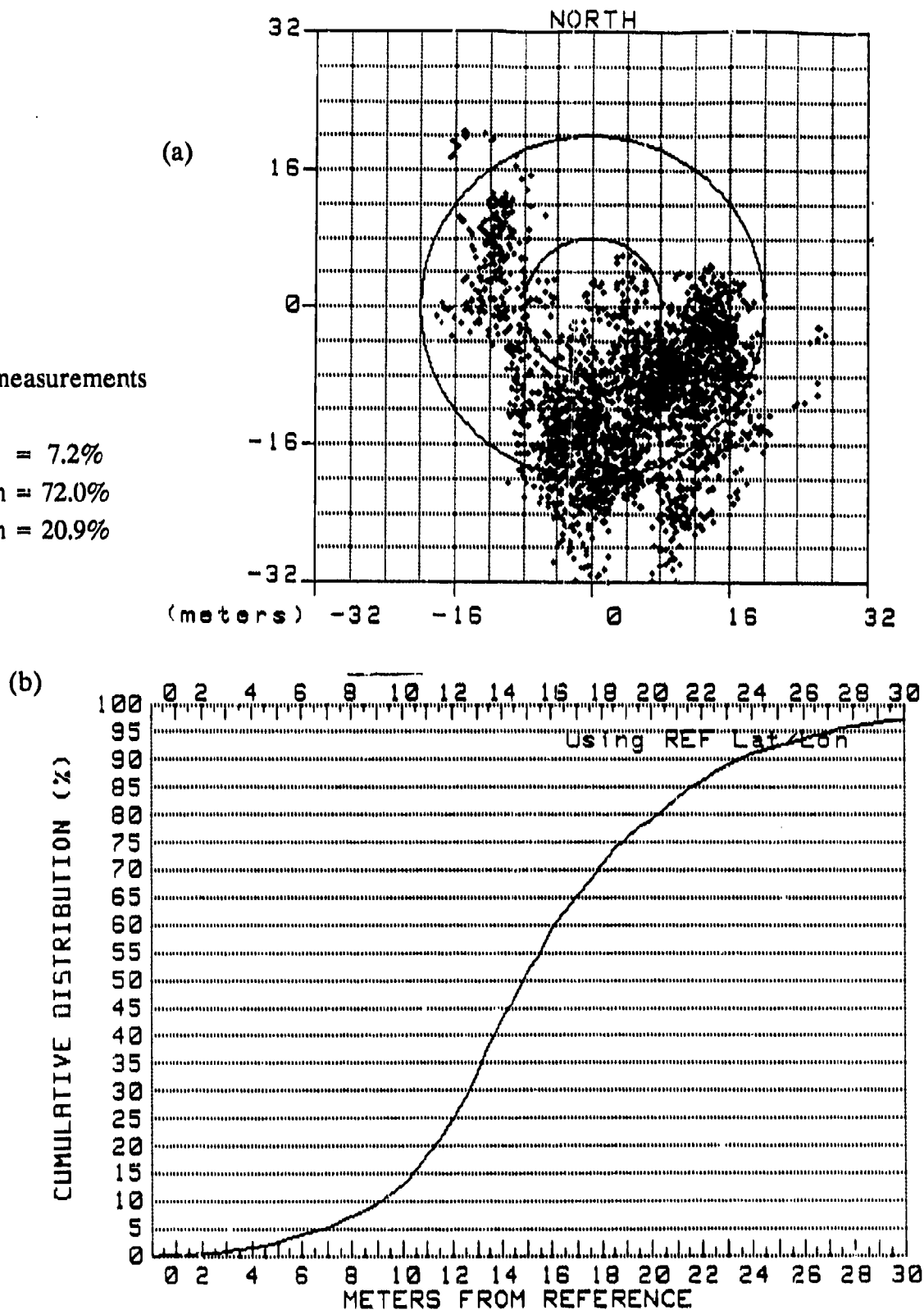
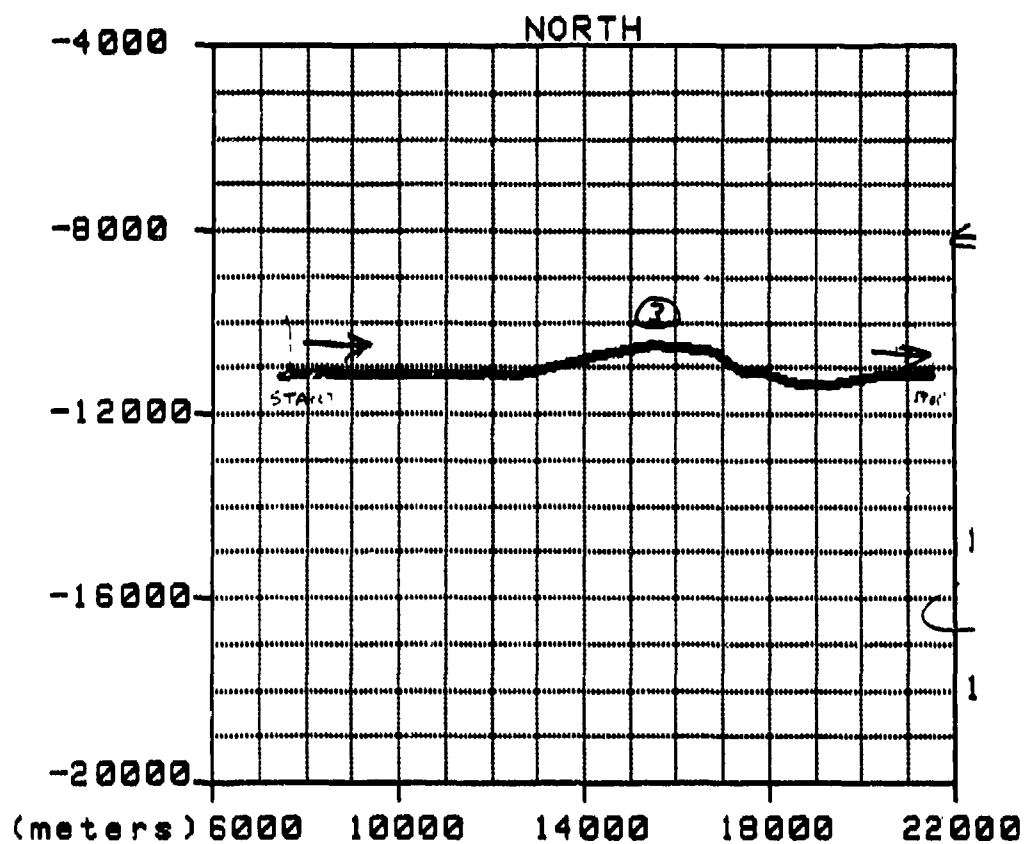


Figure 6-7. Differential Loran-C Positions Relative to Differential GPS During Q-route Survey Leg #1



20 October 1988

1130 - 1205R

Event No.

3

Vessel altered intended track to investigate previous sonar contact (historical find)

Figure 6-8. Trackline Plot of Route Survey Leg #2

1836 measurements

$\leq 8\text{m} = 22.7\%$

$\leq 20\text{m} = 59.0\%$

$> 20\text{m} = 18.2\%$

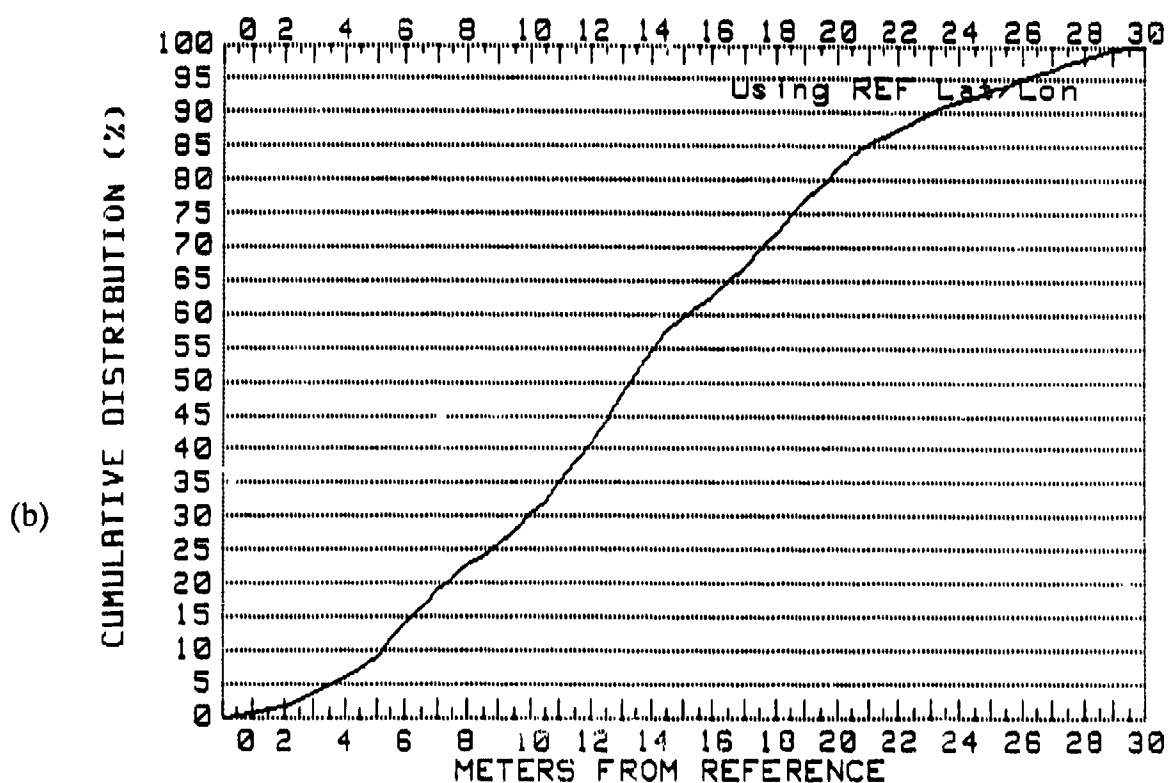
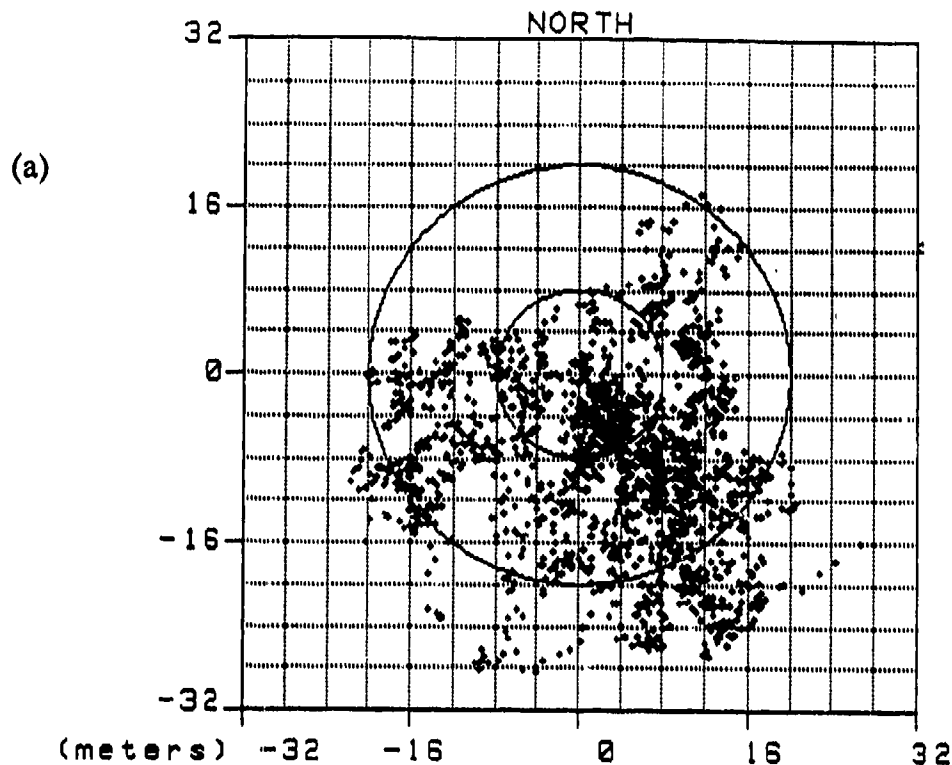
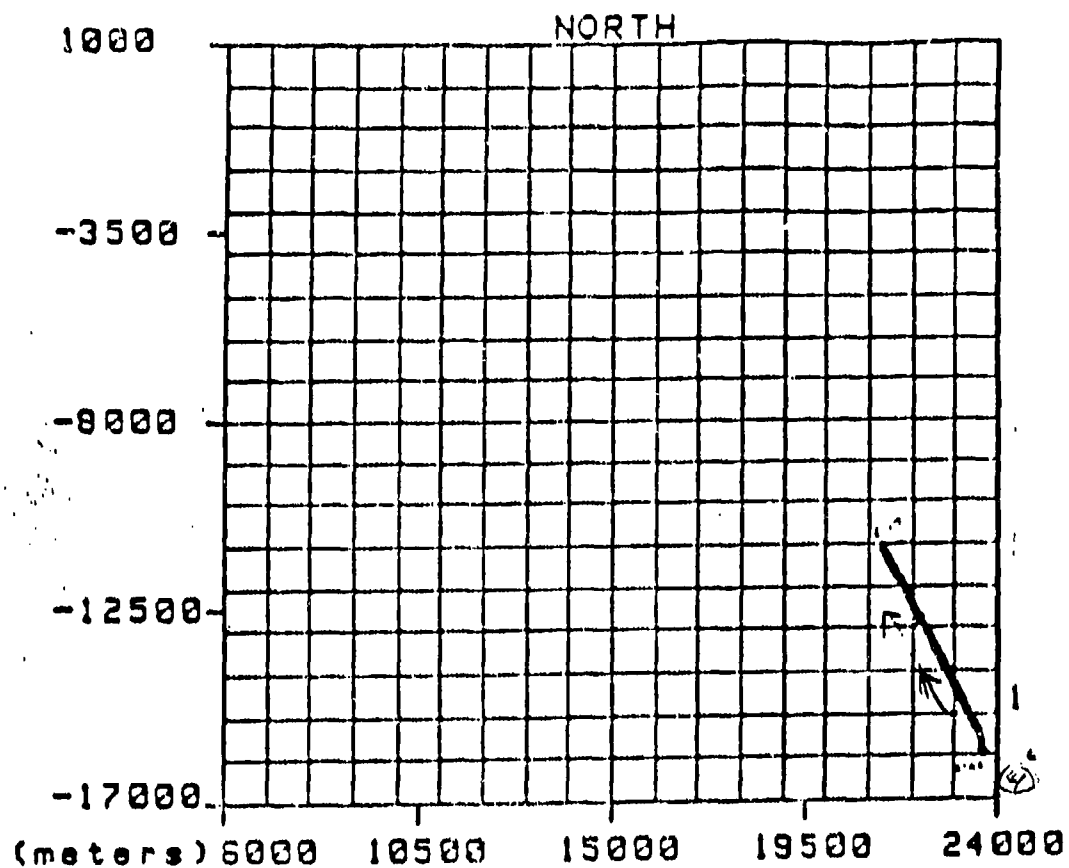


Figure 6-9. Differential Loran-C Positions Relative to Differential GPS
During Q-route Survey Leg #2



20 October 1988

1255 - 1340R

Event No.

4

Farthest at-sea location that Q-route survey operations were conducted during trials.

Figure 6-10. Trackline Plot of Route Survey Leg #3

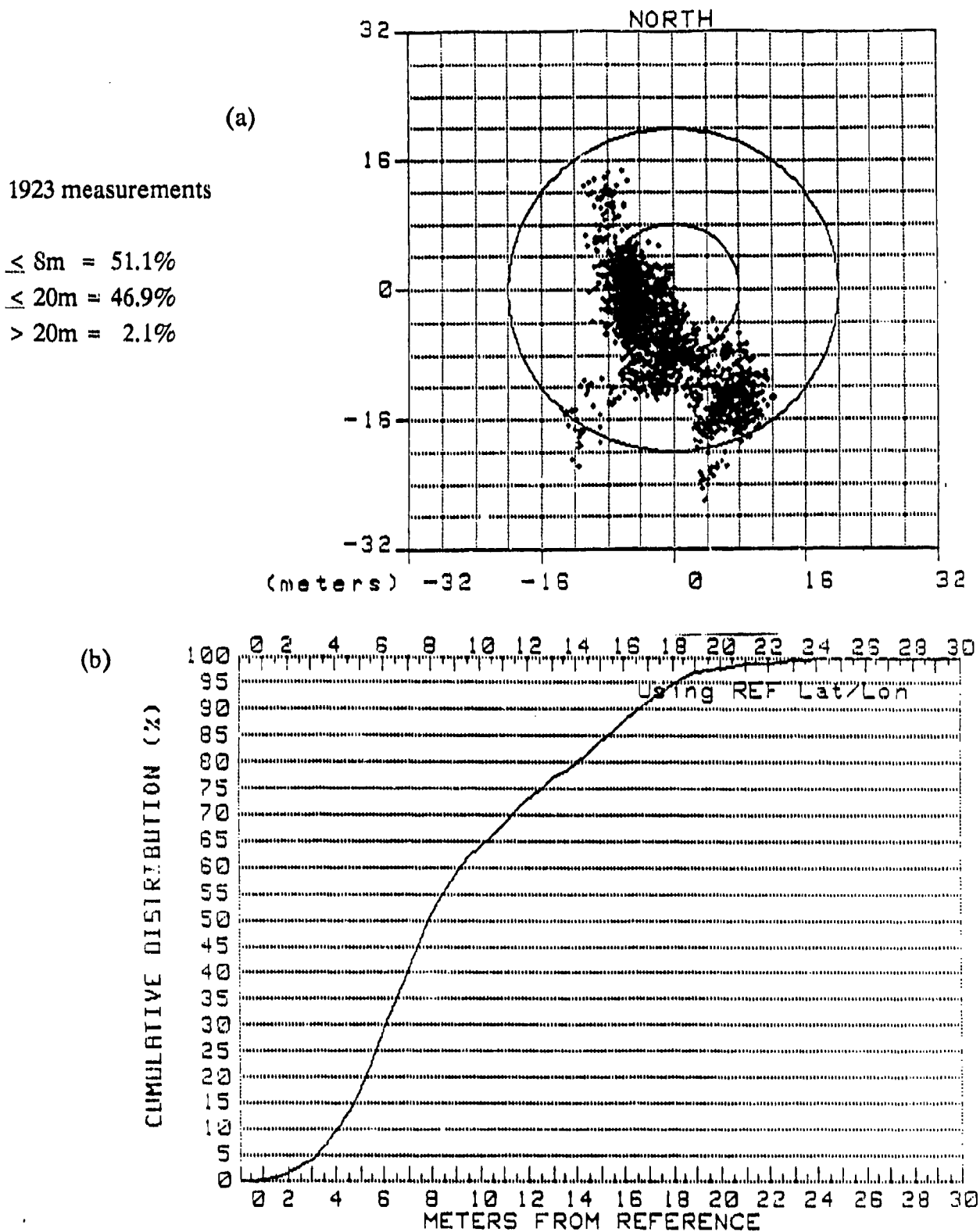
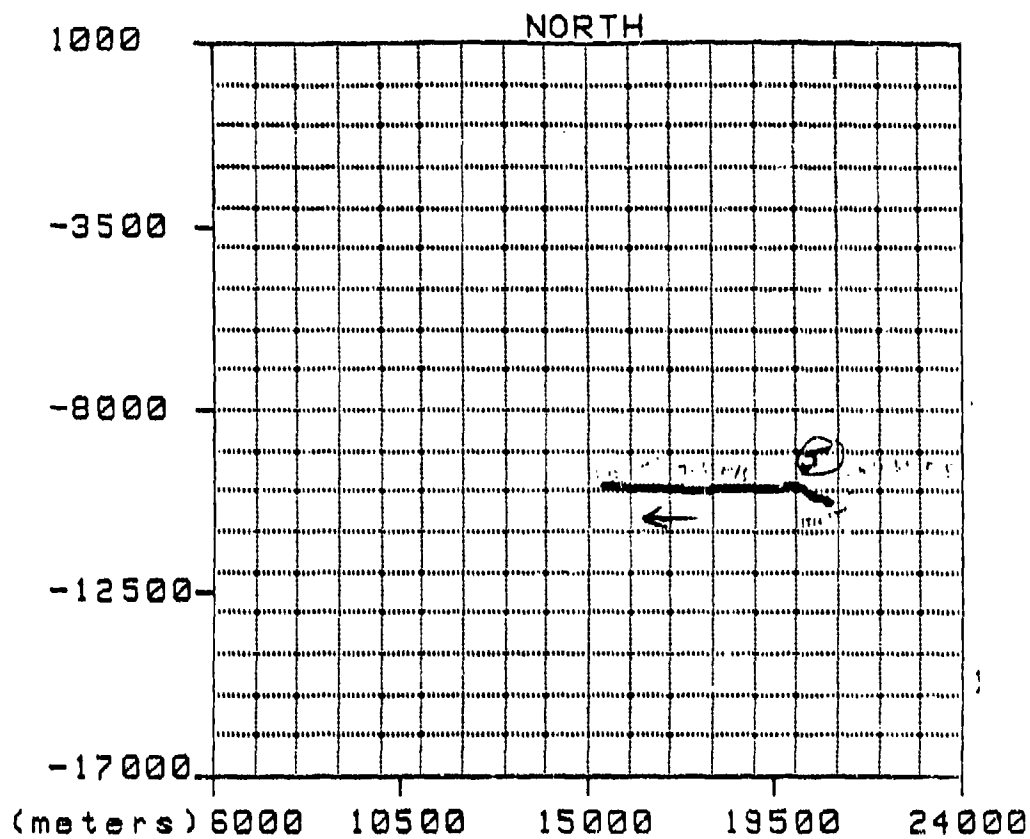


Figure 6-11. Differential Loran-C Positions Relative to Differential GPS During Q-route Survey Leg #3



20 October 1988

1349 - 1407R

Event No.

5

Returned to vicinity of previous route survey leg

Figure 6-12. Trackline Plot of Route Survey Leg #4

825 measurements

$\leq 8\text{m} = 28.7\%$

$\leq 20\text{m} = 68.7\%$

$> 20\text{m} = 2.5\%$

(b)

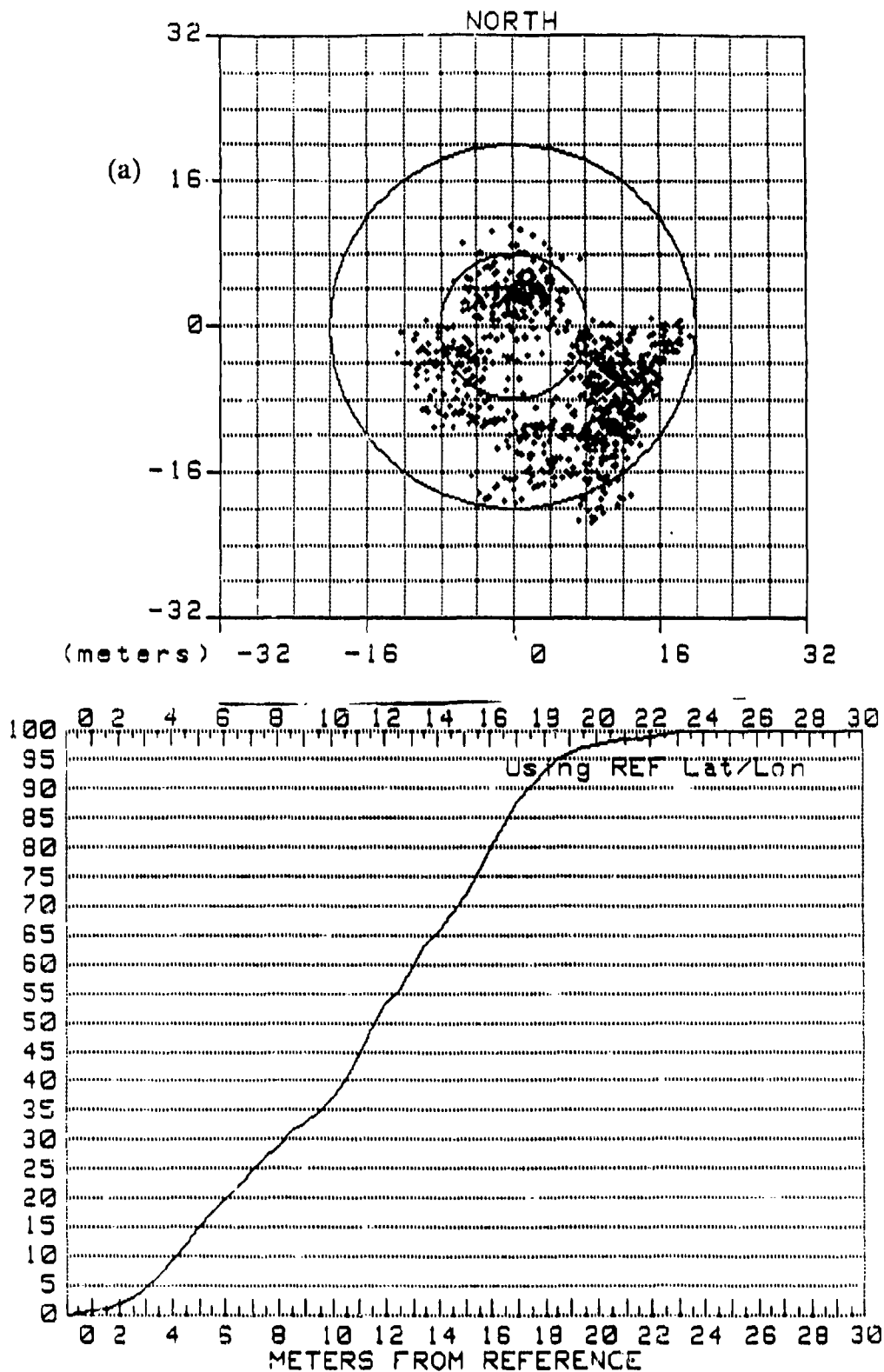


Figure 6-13. Differential Loran-C Positions Relative to Differential GPS
During Q-route Survey Log #4

During the two months that Q-route survey operations were being conducted, there were days when DLC could not be provided by the USCG R&D Center. At these times, Loran-C without the differential corrections was used. As specified in the COMINELWARCOM Route Survey TACMEMO, in those areas where Racal-Decca HYPERFIX is not available, Loran-C is the most preferred radio navigation system for route survey. While Loran-C may not provide an adequate degree of geodetic accuracy, it does provide a high degree of repeatability (Ref. 14). Additional factors that contribute to the suitability and effectiveness of using Loran-C is its availability (broad geographic coverage) and high reliability. During the two months of route survey operations, there was only one 30 minute time period when Loran-C was not fully available.

6.5.2 Side Scan Sonar Procedures: Observed Results

As specified in the COMINELWARCOM Route Survey TACMEMO, there are prescribed procedures/tactics associated with operation of a side scan sonar when used for a route survey mission. However, the results that can be achieved by side scan sonar imaging techniques have some limitations (Ref. 14). The recognition and identification of seafloor objects that have mine-like characteristics is not a refined process. The relatively small size of a mine-like object, the repeatability of the sonar image, the precision of the navigation/positioning system, environmental effects, and the inability to determine actual mine-like targets with other bottom features/objects are a number of the factors that contribute to the difficulty of using side scan for route survey.

The following section discuss, in general terms, how various factors can influence the likelihood of detecting mine-like objects when using side scan sonar. For a more detailed explanation, it is recommended that References 13, 15, 16, 17, & 18 be consulted. Side Scan Sonar Record Interpretation (Ref. 13) is a particularly well-written and illustrated publication that provides a non-technical explanation of side scan sonar applications and record interpretation.

1. Operating Frequency. The Klein 595 side scan sonar operates as a simultaneous, dual-frequency side scan sonar. The combination of relatively high contact resolution with the 500 kHz frequency, and the relatively longer range that can be attained with the 100 kHz frequency, contributed to optimizing both near and far-range contact detection. Since the Klein 595 sonar recorder can display both the 100 kHz and the

500 kHz at the same time, a sonar contact was usually detected and marked on the side scan recorder paper record using both frequencies.

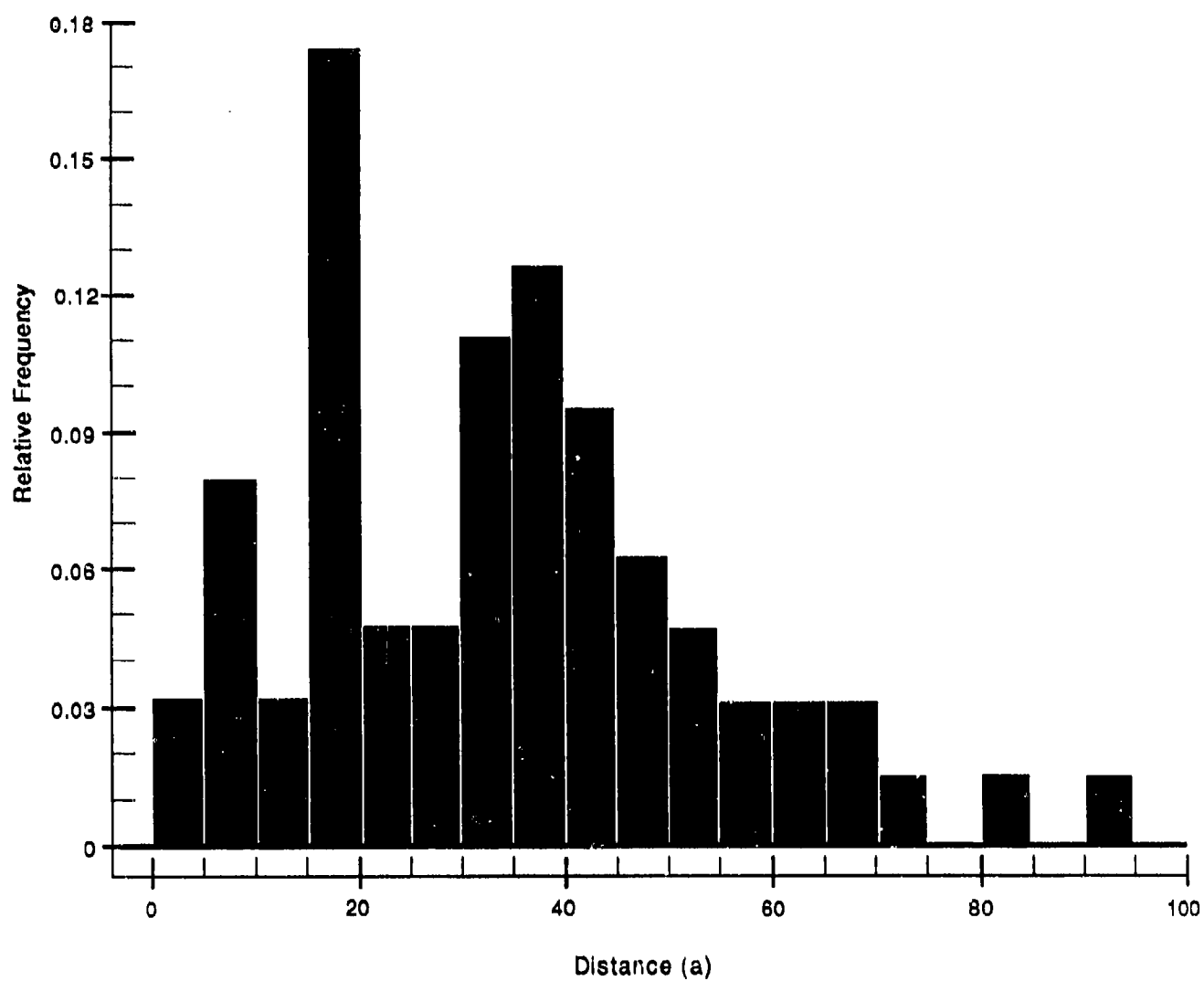
Analysis of the side scan sonar records (paper trace) of 63 contacts exhibiting mine-like characteristics (shape and dimensions) indicates that in most instances, a contact could be discriminated equally well on the 100 kHz or 500 kHz record. There were only four recorded occasions where the contact was more discernable on the 500 kHz record.

2. Range Setting. The COMINEWARCOM Route Survey TACMEMO specifies a 150 meter range setting when streaming a 100 kHz towfish. Since the Klein 595 towfish can operate as a simultaneous, dual-frequency (100 & 500 kHz) side scan sonar, a range setting of 100 meters was used since this is the maximum effective range for 500 kHz. The mean distance (average) for a detected mine-like object from the towfish was 35 meters. As shown in Figure 6-14, the relative frequency of side scan sonar contacts as a function of the horizontal distance from the towfish to the observed sonar contact indicates that 100 meters may be the maximum effective range in which a mine-like object will be detected when a typical USN/USCG operator is using side scan sonar--even with the 100 kHz frequency.

3. Towfish Altitude. The altitude of the towfish is normally regulated by the scope (length of payout) of the towcable and the speed of the survey vessel. As a general rule of thumb, towfish altitude (height above the seafloor) should be 10-20% of the range setting. As shown in Figure 6-15, 67% of the side scan sonar contacts were detected when the towfish was 8-12 meters above the seafloor. No contacts were detected when the towfish altitude was above 30 meters.

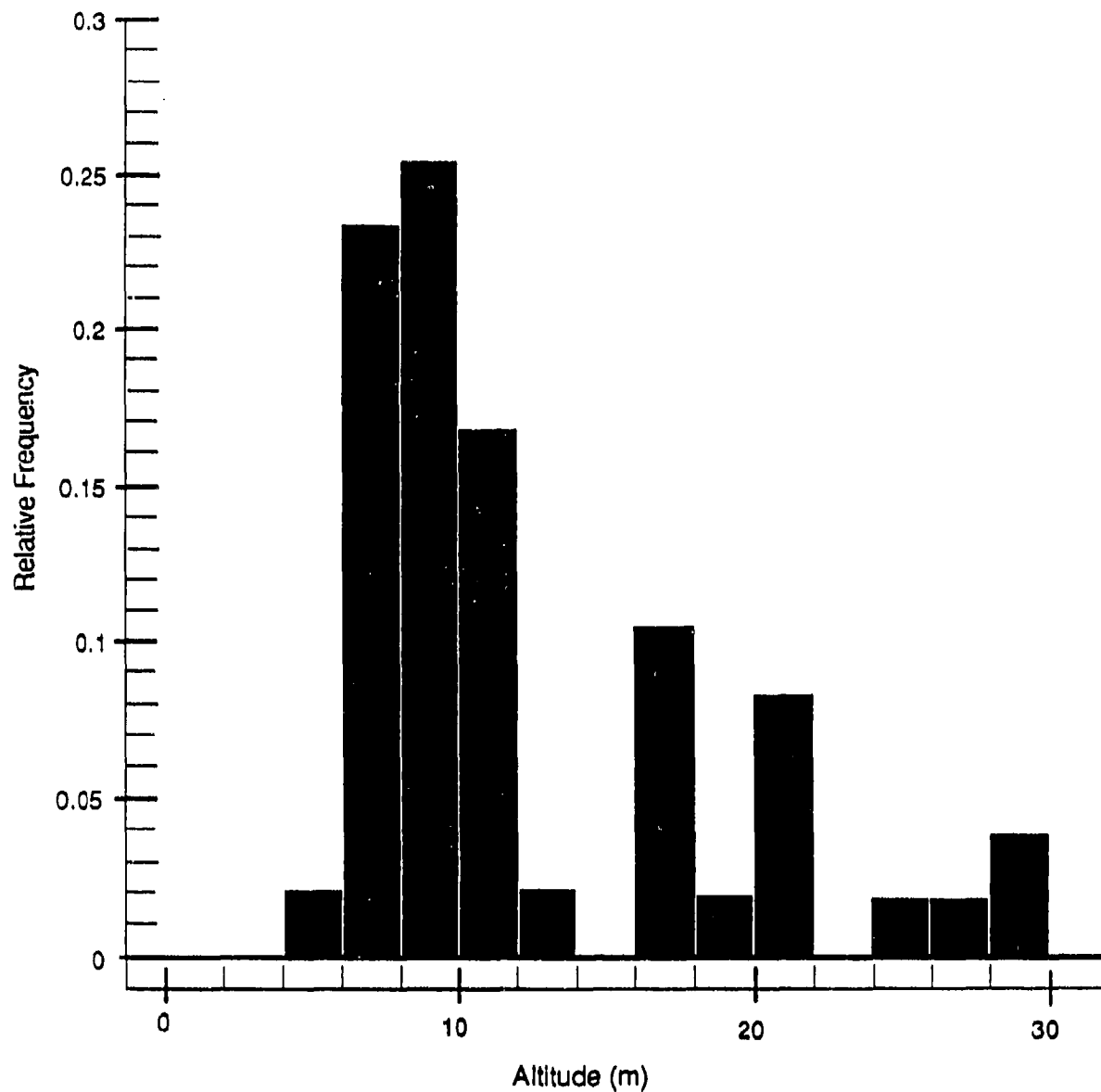
4. Towfish Speed. The speed that a towfish travels has a direct effect on the size of objects that can be detected. In general, the lower the speed the higher the probability of detection for smaller-sized objects. Although towfish stability is a consideration, the actual speed that a towfish travels through the water is less important than its speed-over-ground (SOG). As specified in the COMINEWARCOM Route Survey TACMEMO, four knots is considered a maximum effective speed.

As discussed previously, the minimum vessel speed of 5.5 kts for the 65' WYTL did not hamper effective route survey operations if the vessel was heading into a current. As



HORIZONTAL DISTANCE FROM TOWFISH TO CONTACT

Figure 6-14. Relative frequency of recorded side scan sonar contacts ($n=63$) as a function of horizontal distance from towfish to contact.



ALTITUDE OF TOWFISH ABOVE SEAFLOOR

Figure 6-15. Relative frequency of recorded side scan sonar contacts (n=63) as a function of altitude of towfish above the seafloor

shown in Figure 6-16, 87% of all side scan sonar contacts were detected when the towfish has a SOG between 2.6 and 3.6 knots.

5. Seafloor Topography/Composition. A wide range of seafloor conditions were encountered during route survey operations--ranging from a smooth, level bottom to rocky areas with gorges and ledges. Although no controlled testing was performed to determine the probability of detection for various sized objects located under varying seafloor topography conditions, the results shown in Table 6-5 indicate that sonar contacts exhibiting characteristics of mine-like objects were detected under all bottom topography conditions encountered. If it can be assumed that mine-like objects are randomly distributed along the Q-route, then the frequency of contacts reported for a particular bottom type would likely be proportional to the bottom types encountered.

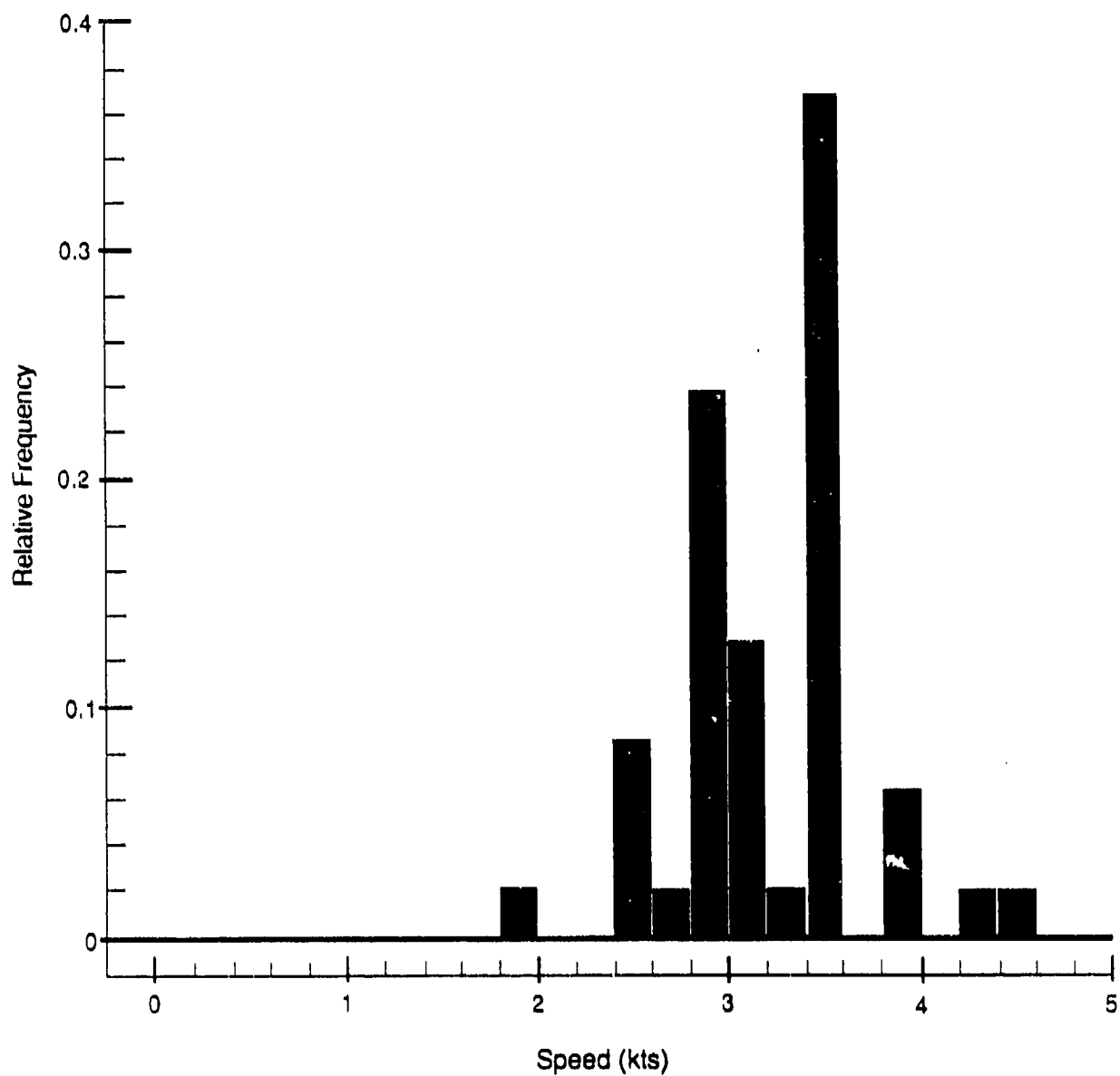
TABLE 6-5

RELATIVE FREQUENCY (%) OF SIDE SCAN SONAR CONTACTS REPORTED
DURING VARYING SEAFLOOR TOPOGRAPHY CONDITIONS VERSUS THE
FREQUENCY OF SEAFLOOR TOPOGRAPHY CONDITIONS ENCOUNTERED
(N=63)

<u>Seafloor Topography</u>	<u>Conditions Encountered</u>	<u>Contacts Reported</u>
Smooth	32	21
Uneven	28	38
Rough/sand waves	8	19
Very rough/sand ridges	15	5
Scattered rocks	12	14
Very rocky/outcrops	5	3
	100	100

6.5.3 Sea-state/Environmental Conditions

Sea-state or adverse environmental conditions can significantly affect any underway operation. It can be a significant factor affecting the successful conduct of Q-route survey operations when a 65' WYTL or a 55' ANB vessel is used. During the two months of at-sea trials, route survey operations were conducted in conditions up to sea-state 4. However,



TOWFISH SPEED OVER GROUND

Figure 6-16. Relative frequency of recorded side scan sonar contacts (n=63) as a function of towfish speed over ground.

67% of the total on-task hours occurred during sea-state 1 or 2 conditions. Although not necessarily correlated, this frequency of sea-state encountered is proportional to the percent of side scan sonar contacts reported during sea-state 1 and 2 conditions (69%). Although mine-like objects were detected during sea-state 4 conditions, deployment and recovery of the towfish and acoustic tracker hydrophone became more hazardous. Additionally, the side scan sonar towfish was less stable and its performance was degraded.

In general, when it is too rough to a 55' ANB or a 65' WYTL to perform routine underway operations, it is too rough to conduct effective route survey operations.

7. CONCLUSIONS AND RECOMMENDATIONS

1. Commercially-available systems are suitable for conducting Q-route Survey operations. In order to effectively accomplish a Detailed Route Survey mission, an integrated system configuration comprised of side scan sonar, display/data management system, and navigation/positioning sub-systems is required. The USA-manufactured components that were selected by the Royal Australian Navy for their Mine Surveillance System were found to be particularly suitable and effective.
2. U.S. Coast Guard vessels, including a 55' ANB, a 65' WYTL, and a 180' WLB, are suitable platforms from which to conduct Q-route survey operations when utilizing side scan sonar. In terms of installing or operating an Integrated Route Survey System (IRSS), there were no significant vessel-related constraints associated with available working space, minimum vessel speed, or electrical power. Given the advantage of a below deck (interior) working space and maximum vessel speed, a 55' ANB is the more capable platform from which to conduct coastal Q-route survey operations. With a portable equipment shelter embarked, a 180' WLB is a highly suitable platform for conducting off-shore Q-route survey operations.
3. Three technicians working with 4-5 individuals from Ship's force can install an Integrated Route Survey System (IRSS) onboard a 55' ANB or 65' WYTL in one working day. This does not include the time required to fabricate the hydrophone swing-arm assembly. Less time is required when embarking a Portable Equipment Shelter (PORSH) onboard a 180' WLB.

Recommendation:

A three-person side scan sonar/route survey "Tiger-Team" could be established and trained to install, maintain, and supervise the operation of IRSS. Depending upon the number of IRSS equipment suites that may be procured, there should be at least one USCG active duty and one USCG reserve team per district for each IRSS equipment suite.

4. A joint-service approach to Q-route Survey operations that involves both USCG and USN personnel can be an effective utilization of existing skills and talent. USCG and USN personnel were quickly able to understand the concept and capably perform route survey operations. Effective results were achieved when assigned USN personnel were assigned to operate the IRSS consoles, while USCG personnel were responsible for piloting the vessel and deploying/recovering the side scan sonar and acoustic hydrophone.

Recommendation:

Joint-service Q-route Survey operations involving USCG and USN reserve personnel may be a particularly effective means to accomplish both MARDEZ operational and training/readiness missions. Since Reserve personnel rotate less frequently than active duty personnel, trained and "certified" USCGR teams may be the most effective means of assuring necessary experience and continuity is available for this MARDEZ mission.

5. After a brief indoctrination, and with only a moderate amount of on-board training, both USCG and USN personnel were able to effectively operate IRSS during at-sea operations. However, at least two weeks of formal training will probably be required for an individual to become proficient in overall system installation, operation, trouble shooting, and maintenance.
6. During the two-month underway period that IRSS was operated from the 65' WYTL and the 55' ANB, there were 22 instances when IRSS was not able to fully perform a Detailed Q-route Survey Mission. Most were instances classified as "minor failures" which did not result in a significant adverse impact on the overall mission. Only one critical failure occurred that prevented the vessel and crew from performing its mission.

7. Based on observations made during two months of underway operations, there are three primary factors that impact the effective conduct of route survey operations:

- a. Precision radio navigation system
- b. Side scan sonar procedures/tactics
- c. Sea-state/environmental conditions

The most critical factor is the availability and performance of the radio navigation system.

8. When used as the precision navigation system for Q-route survey operations, Differential Loran-C provided a geodetic accuracy of better than 20 meters for 88% of the positioning solutions.

9. The published tactics and procedures on the conduct of Q-route Survey operations when using an integrated navigation/data management system are not well defined. Factors that appear to influence the likelihood of detecting mine-like objects when using side scan sonar included: the operating frequency of the side scan sonar (e.g., 100 kHz, or simultaneous 100/500 kHz), range setting, towfish altitude above seafloor, towfish speed over ground, and seafloor topography/composition. Additional controlled testing and validation is needed to derive a more definitive determination of those factors associated with probability of detection and effective search width when using side scan sonar for Q-route survey operations.

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APPENDIX A

OPERATIONAL TEST PLAN

NEW LONDON Q-ROUTE SURVEY DEMONSTRATION PROJECT

**U.S. Coast Guard Research and Development Center
Avery Point
Groton, Connecticut 06340**

September - November 1988

[B L A N K]

SECTION 1 - INTRODUCTION

101. Purpose. To evaluate a joint-service Q-Route survey project in New London, CT, during October 1988. Associated with the project is an evaluation of USCG vessels that are equipped with the QUILS II Integrated Navigation and Data Management System developed by Meridian Ocean Systems, San Jose, CA. The USCG vessels will be manned by USCG reserves/regulars while QUILS II will be operated by USN reserves/regulars.

102. Background. Current U.S. Naval strategy has reordered the responsibilities for defense of U.S. coastal waters and harbors and established the Maritime Defense Zone (MDZ). Naval warfare and USCG statutory missions in the MDZ theater-of-operations include shallow-water ASW, mine countermeasures (MCM), protection of sea line of communications (SLOCS), coastal surveillance, and port security/harbor defense. COMUSMARDEZLANT and COMUSMARDEZPAC are the Navy Third Echelon Commands staffed jointly by USCG/USN that report directly to CINCLANTFLT/CINCPACFLT and are composed of Coast Guard and Navy forces when activated.

A New London, CT, Q-route survey project was first proposed by Commander, First Coast Guard District in December 1987, and was approved by USCG Commandant (G-ER) as a Select Project on 31 March 88. This project was endorsed by USCG Research and Development Center and incorporated into the MCM portion of the USCG Defense Readiness Program. This program includes mission review, technology assessment, requirements definition, capabilities assessment, and an evaluation of equipment, systems, tactics, platforms, and personnel. Tests and evaluations (T&E) include both technical evaluations that determine specific capabilities of a particular component, and operational evaluations that measure effectiveness of the integrated system in meeting mission requirements.

The primary focus of the New London Q-Route Survey Demonstration Project is an evaluation of systems and tactics in an operational environment rather than a technical evaluation of any specific equipment/system under tightly controlled conditions. This project thus provides an opportunity to conduct an operational evaluation (testing) of the capability and performance of QUILS II when installed on USCG vessels and operated by USCG/USN personnel.

QUILS II was recently selected by the Royal Australian Navy (RAN) for Q-Route survey operations as their Mine Surveillance System (MSS). The selection was made after extensive at-sea comparative evaluations of some of the most advanced commercial navigational, data management, sidescan sonar, image processing,

and acoustic tracking systems available on the world market. QUILS II and all components selected by the RAN for their MSS are made in the USA. QUILS II is a follow-on to the QUILS I system, recently used by the COOPMINERON ONE on the west coast.

103. Scope. Q-Route survey operations will be conducted in accordance with the COMINELWARCOM Route Survey TACMEMO (Edition 187). Route survey data will be submitted in a format suitable for inclusion into the COMINELWARCOM Q-Route Survey Data Management System. USCG vessels involved include a 65' WYTL and a 55' ANB. If available, a NRF COOP Trainer Vessel (CT) may participate as well.

QUILS II, as an integrated system, is comprised of a number of sub-systems/components including side-scan sonar, precision navigation, acoustic tracker, helm display, and computer-assisted plotting, display, and analysis. Personnel will be trained in the installation, operation, and maintenance of QUILS II and will be provided training in Q-Route Survey procedures/tactics.

103. System Description.

QUILS II

a. CPU Subsystem

- (1) HP-330 Processor
includes: QUILS II software
- (2) High resolution color monitor
- (3) Hard disc drive
- (4) Cassette Tape Drive
- (5) A-3 size drafting plotter
- (6) Color printer

b. Navigation Subsystem

- (1) Racal Decca HYPERFIX
includes: receiver/controller and antenna
- (2) ACCUFIX 500 Loran-C
includes: receiver/controller and antenna
- (3) Sperry SR-50 Ships gyrocompass with Lehmkuhl LR-60 digital interface

c. Contact Processing Subsystem

- (1) Klein 595 sidescan sonar
- (2) Tracor Model 620 Target Signal Processor

SECTION 2 - ADMINISTRATIVE INFORMATION

201. General. General responsibilities of activities involved in this testing, and points of contact are provided in this section. Close liaison is essential to the timely planning and successful conduct of the project.

202. Responsibilities.

a. USCG R&D Center

- (1) Assign an Operational Test Director (OTD) who will supervise the conduct of the testing as described in this test plan.
- (2) Prepare appropriate changes to the test plan.
- (3) Coordinate arrangements for services and equipment.
- (4) Conduct briefings for representatives of all participating units.
- (5) Analyze test results and publish an evaluation report.

b. COMINEWARCOM

- (1) Provide on-scene Unit Training in Q-Route Survey procedures and tactics. This two-day program would include both classroom and underway training.
- (2) Assign a representative to coordinate with USCG R&D Center during testing.
- (3) If available, provide a Test Evaluator to observe all or a portion of the test.

203. Points of Contact

<u>Title</u>	<u>Code</u>	<u>Phone</u>
Operational Test Director Dr. Lee Alexander	USCG R&D Ctr	FTS 642-2639 (203) 441-2639
CDR James McClinton, USCG	COMINEWARCOM N4B	(803) 743-5227
Project Officer LT Ray Marvel	USCG DIST ONE (re)	FTS 223-8528 (617) 223-8528

204. Visitor Control. Approval for visitors/vessel riders will be granted for valid requirements, for required technical assistance, or on a genuine need-to-know basis. Requests for visits during project operations will be addressed to Commanding Officer, USCG R&D Center (COGARD R&DC, GROTON, CT) info Commander, Coast Guard District ONE (CCGDONE). Commanding Officer, USCG R&D Center will coordinate the requests with CCGDONE.

SECTION 3 - SCOPE OF EVALUATION

301. Objectives

- a. Operational Effectiveness. Determine the capability of QUILS II to perform its intended mission:
 - (1) when installed on a USCG platform.
 - (2) when operated by USCG/USN personnel.
- b. Operational Suitability. Evaluate QUILS II in terms of:
 - (1) Reliability
 - (2) Maintainability
 - (3) Availability
 - (4) Maintenance Supportability
 - (5) Compatibility
 - (6) Interoperability
 - (7) Training
 - (8) Technical Documentation
 - (9) Human Factors
 - (10) Safety

302. Evaluation Criteria.

Launch/Recover Towfish

- vessel speed (min/max)
- maximum sea state

System Operation

- vessel speed (min/max)
- vessel handling/maneuverability
- maximum sea state
- currents
- hazards/interference
 - surface vessels (naval, pleasure, fishing, ferry)
 - buoys, lobster buoys, floating debris, subsurface (lobster traps, fishing nets, etc.)

Reliability (4-hr mission)

Mean time between failures (MTBF)

Mean time to repair (MTTR)

User Friendliness (man-machine interface)

303. Testing. Testing operations will monitor the performance of QUILS II in an at-sea/underway environment. These operations will provide the data for evaluation in individual tests of operational effectiveness (E-tests) and operational suitability (S-tests) discussed in Sections 4 and 5.

a. Safety. In the conduct of all operations associated with this project, SAFETY IS PARAMOUNT. No operations will be conducted that, in the opinion of the OTD, the boat coxswain, or the on-scene Test Evaluator, will endanger personnel or equipment.

b. Contractor Assistance. Technical assistance from contractor/manufacturer personnel to install and calibrate the various components of QUILS II during the initial phase of the project will be required. In addition, training assistance associated with system operation and maintenance will be provided. However, during the underway testing and evaluation of the system, no contractor personnel associated with the project will be permitted on board without prior approval of the OTD.

c. Data Collection. Special data sheets for use in testing are contained in Annex A. Copies will be furnished by the OTD to the Test Evaluators. Test Evaluators will administer/complete the data sheets and return them to the OTD.

304. Limitations in Scope. Climatic conditions during the fall months in the New London, CT, area are quite variable and will limit the number of days that a 65' WYTL or a 55' ANB may safely conduct at-sea operations in Long Island/Block Island Sound. For planning purposes, it is not likely that either vessel will be able to conduct Q-route survey operations more than three days per week (on a M-F basis). On those days that a vessel is underway, a normal at-sea employment period for QUILS II shall be at least four hours (on-task). This does not include transit time to and from the OPAREA.

SECTION 4 - OPERATIONAL EFFECTIVENESS

401. Test Operations. Test Operations will involve the underway operation/evaluation of QUILS II on board a USCG 55' ANB and/or a 65' WYTL during the month of October 1988.

402. Test E-1, QUILS II Installation on USCG Vessels

- a. Objective: To determine the effectiveness of QUILS II when installed on and operated from a 55' ANB and/or USCG 65' WYTL.

b. Procedure.

1) QUILS II will be installed on a 65' WYTL the week of 29 August and on a 55' ANB the week of 3 October 1988. QUILS II installation, operation, and maintenance training assistance will be provided by the manufacturer (Meridian Ocean Systems (MOS)).

2) The OTD will observe and record the details of this installation/training process. Selected interviews with both the instructors and trainees will be conducted.

c. Data Analysis. On-scene observations and check list data will be assessed qualitatively by the OTD.

403. Test E-2, QUILS II Operation by USCG/USN Personnel

a. Objective: To evaluate the capability if QUILS II to perform a Q-Route survey mission when operated by a mix of USCG/USN reserves and regulars.

b. Procedure.

1) This test will be conducted following the initial installation, operation, and maintenance training period.

2) The OTD and/or Test Evaluator will observe and record the performance of the "entire QUILS II system" (Man-Machine Interface) during each underway evolution utilizing Data Sheets A and B.

3) Data Sheet C (QUILS II Operator Questionnaire) will be administered at the completion of the project period.

4) The OTD will supervise the collection and analysis of Q-Route Survey data necessary for post-mission analysis. This data will be compiled and submitted, in accordance with the Q-Route Survey TACMEMO, to COMINELWARCOM for inclusion into the Q-Route Survey Data Management System.

c. Data Analysis. On-scene observations and check list data will be qualitatively assessed by the OTD. Questionnaire results will be compiled and quantitatively analyzed. The suitability of the collected Q-route Survey data will be analyzed in terms of coverage, completeness, precision, and accuracy.

SECTION 5 - OPERATIONAL SUITABILITY

501. General. Suitability testing will use the data generated by the operation of QUILS II during at-sea/underway operations. Test objectives, specific procedures, and planned analysis methods are described for each test. Further instructions and definitions are contained in each data sheet.

502. Test S-1, Reliability

a. Objective: To determine QUILS II reliability when performing as an integrated system.

b. Procedures. This test shall be conducted continuously during project operations and will consist of:

(1) Operating QUILS II for as many total underway/ at-sea hours as possible.

(2) Recording the times of QUILS II operations on Data Sheet A (Test Evaluator's Log).

(3) Identifying and recording mission and minor failures on Data Sheet B.

(4) Recording any type of preventive maintenance action that finds a failed component or part.

c. Data Analysis. The following failure definitions apply:

(1) Mission Failures

(a) Critical Failure. One which prevents QUILS II from performing its intended mission.

(b) Major Failure. One which causes QUILS II to lose some operational capability and degrades mission accomplishment. If detected before the mission, it would probably be mission-aborting.

(2) Minor Failure. One which affects performance but can be worked around to avoid impacting the mission.

503. Test S-2, Maintainability

a. Objective: To determine QUILS II maintainability.

b. Procedure. This test will be conducted concurrently with Test S-1 and will consist of recording on Data Sheet C (Maintenance Action Log) the time required for all repair actions.

c. Data Analysis. The following definitions apply:

(1) Active Repair Time - the total clock time required to both locate and repair a malfunction. Repair time equals fault locate time plus fault correct time.

(2) Fault Locate Time - the total clock time required to actively determine the cause of a malfunction.

(3) Fault Correct Time - the total clock time required to correct a malfunction, calibrate if necessary, and conduct a test if required. Included is time spent obtaining repair parts.

504. Test S-3, Availability

a. Objective: To determine QUILS II operational availability.

b. Procedure. This test will be conducted concurrently with all other tests and will use the data recorded on Data Sheets B and C. QUILS II, as a system, will be checked for operational availability at the start of each day, whether scheduled for underway/at-sea operations or not.

c. Data Analysis. Availability will be determined as the ratio of the "number of times the system performed as required" (from start to finish) to the "total number of times its performance was required." "Total number of times its performance was required" shall be the sum of the number of employments attempted and the number of employments scheduled but not attempted because the system was known to be inoperable.

505. Test S-5, Compatibility

a. Objective: to determine the compatibility of QUILS II as a Q-route survey system when operated from a USCG 65' WYTL and/or 55' ANB and operated by mixture of USCG/USN regular and reserve personnel.

b. Procedure

(1) This test will be conducted concurrently with all other testing and will consist of noting the capabilities and limitations of both vessels and personnel to conduct Q-route survey operations.

(2) The OTD and/or designated Test Evaluators will observe at-sea operations and conduct interviews with selected individuals.

(3) Data Sheet "D" will be completed near the end of project operations.

c. Data Analysis. Interview responses and OTD/Test Evaluator observations will be assessed.

506. Test S-6. Interoperability

a. Objective: to determine the interoperability of QUILS II when using one of several precision navigation inputs.

b. Procedure. LORAN-C, Racal-Decca HYPERFIX, and Differential LORAN-C will each be evaluated as precision navigation inputs to QUILS II. Differential GPS will be used as the "truth system." A more detailed description of this test is provided in Annex B.

c. Data Analysis. (see Annex B)

507. Test S-7. Training

a. Objective: to determine the adequacy of operator and maintenance technician training that was provided by Navy and/or Contractor personnel.

b. Procedure. Personnel who were trained to operate and maintain QUILS II will be observed by the OTD/Test Evaluators in the performance of their duties. Data Sheet "D" (Support Questionnaire) will be completed by all operators and maintenance personnel near the end of the project operation. Personnel interviews will be conducted as necessary.

c. Data Analysis. OTD observations, data sheet, and interview responses will be assessed.

508. Test S-8. Technical Documentation

a. Objective: To determine the adequacy and accuracy of technical documentation (e.g., technical manuals, maintenance manuals).

b. Procedure.

(1) Data will be collected throughout the testing period. Test participants, upon completion of corrective/maintenance actions, will submit Data Sheet B (Maintenance Action Log), noting those instances where technical documentation was incomplete, inaccurate, or misleading.

(2) At the completion of the test period, all maintenance and operator personnel will complete Data Sheet C (Operator's Questionnaire).

c. Data Analysis. Data Sheets B and C will be compiled and evaluated to determine the adequacy of technical manuals.

509. Test S-9, Human Factors

a. Objective: To determine the ease of operation and maintenance of QUILS II

b. Procedure.

(1) The OTD and designated Test Evaluators will observe QUILS II operator/maintenance personnel in the performance of their duties.

(2) Data Sheet C (Operator's Questionnaire) will be administered at the end of the project.

(3) Personnel interviews will be conducted as necessary.

c. Data Analysis. Data Sheet and interview responses will be compiled and analyzed. Important criteria for evaluation include: factors associated with the configuration of QUILS II which affected the performance of required operation and maintenance tasks, manning levels, task loading, skill requirements, and "user-friendliness" (man-machine-interface).

510. Test S-10, Safety

a. Objective. To evaluate safety considerations associated with the operation of QUILS II when deployed from USCG vessels and operated by USCG/USN personnel.

b. Procedure.

(1) This test will be conducted concurrently with all other tests and will consist of documenting any potential or actual safety hazards associated with the use of QUILS II in the conduct of Q-Route survey operations.

(2) All potential or actual safety hazards will be documented on Data Sheets A, B, and C.

c. Data Analysis. The OTD will compile and assess the results.

References

- a) Operational Requirement (OR) for MDZ "Q" Route Survey Equipment (OR # 188-03-87), promulgated 13 Nov 87
- b) Maritime Defense Zone (MDZ) Resource Requirements (USCG COMDT INST 7110.1A), dtd 15 Apr 88
- c) USCG Defense Readiness Project Master Plan (Version 3), dtd 31 May 1988
- d) Select Project Proposal: Q-Route Survey Project, CCGD1 ltr 3530 of 22 Dec 87
- e) Development of Q-Route Survey Program: Select Project Proposal, COMINELWARCOM msg 191759Z Jun 88
- f) Q-Route Survey Demonstration Project, COMDT COGARD msg 031807Z Jun 88
- g) Q-Route Survey Demonstration Project, OPORDER (NO. 05-88), dtd 9 May 88
- h) Operational Test Director Guide, COMOPTEVFORINST 3960.1E, dtd 2 Mar 87

TEST EVALUATOR'S DAILY LOG

Date _____

Vessel _____

Persons onboard (not including vessel crew):

<u>Name</u>	<u>Rate/Rank</u>	<u>Duties</u>
-------------	------------------	---------------

Environment

Weather Conditions:

Wind Direction _____ Velocity _____

Sea State _____ Direction _____

Other Factors _____

Evolutions/time periods

	<u>Start</u>	<u>Stop</u>
departed pier _____		
in-transit to assigned area _____		
conducted route survey ops _____		
off-task periods (describe) _____		
return transit to port _____		
returned to pier _____		

Coxswain's Assessment of Underway ops:

Brief Narrative of Events (make specific note of any problems encountered; use back side if necessary):

DATA SHEET C - OPERATOR'S QUESTIONNAIRE

NAME: _____

RANK/RATE: _____ TIME IN SERVICE: _____

TIME IN RANK/RATE: _____ PREVIOUS RATE: _____

RELATED NECs: _____

List any training received for this equipment (e.g., Navy school, factory and/or OJT).

List any training received on similar or related equipments.

Briefly describe any prior experience you consider helpful in learning to operate or maintain this equipment.

****READ BEFORE FILLING OUT QUESTIONNAIRE****

1. Answer all questions based upon your own experience and not upon what other operators have said, unless the question specifically asks you to do so.
2. You are part of the operational test crew. The data you provide in this questionnaire will be used to evaluate the equipment/system, not you. The equipment was to be designed for your rate, training, and background. We want to estimate how close the designer comes to accomplishing this goal.
3. When writing is required, answer the question without worrying about grammar or spelling, it need only be readable. Be brief, even if it means not using complete sentences. Cross out and use arrows or pictures if you like; just communicate in any way possible.
4. When answering questions, think in terms of how useful things were in helping you carry out your assigned tasks.
5. At the end of the questionnaire, make any comments that you think would be helpful in the evaluation.

USCG R&D CTR TEST PLAN DR-1

1. Can the equipment be satisfactorily operated using the prescribed procedures/tactics?

Yes _____ No _____

2. Is there any mechanical work required of you as an operator which is troublesome?

No _____ Yes _____ If yes, describe _____

3. Is the equipment fatiguing to operate?

No _____ Yes _____

4. Do you have confidence in the performance of equipment?

Yes _____ No _____ If no, explain _____

5. Are the "best" techniques for operating the equipment different from those given in the training sessions or the manuals?

No ____ Yes ____ If yes, describe _____

6. Do you consider QUILS II to be hazardous to operate?

No ____ Yes ____ If yes, describe _____

7. Do you operate all the equipment in this system?

No ____ Yes ____ If no, why not? _____

8. Do you consider your rate appropriate for operating the equipment?

Yes ____ No ____

9. Can the equipment be operated without the benefit of going through operator's school first?

No ____ Yes ____

10. Do you feel that prior experience with similar equipment is necessary to become a good operator?

No ____ Yes ____

11. Is there any specific knowledge that was not covered during the training sessions that you needed in order to operate the equipment?

No ____ Yes ____ If yes, describe _____

12. What additional training would you like to see provided if there was a formal (school) operator training on the equipment?

13. Is there any particular manipulation of the equipment that was particularly difficult to operate?

No ____ Yes ____ If yes, describe _____

14. Are the controls on the equipment compatible with any special handwear (gloves or mittens) that you might have to wear?

No ____ Yes ____ If yes, name and describe _____

15. Are the corrective maintenance task procedures (including adjustment calibration, troubleshooting, and repair) clearly and accurately specified in the system/equipment manuals?

Yes ____ No ____

16. Did you notice any functional or operational incompatibilities with any interfacing equipment?

No ____ Yes ____ If yes, describe _____

17. Is your rate appropriate for doing each of the following maintenance tasks:

-Fault detection?Yes ____, No ____
Fault location?Yes ____, No ____
Part removal?Yes ____, No ____
Part repair?Yes ____, No ____
Part replacement?Yes ____, No ____
System checkout?Yes ____, No ____
Calibrations?Yes ____, No ____

Comments: _____

18. Are the procedures for any of the following maintenance tasks difficult to follow or understand?

Fault detection?Yes ____, No ____
Fault location?Yes ____, No ____
Part removal?Yes ____, No ____
Part repair?Yes ____, No ____
Part replacement?Yes ____, No ____

System checkout?Yes ____, No ____
Calibrations?Yes ____, No ____

If yes, describe _____

19. Are there any specific aspects of the following maintenance tasks which are extremely difficult?

Fault detection?Yes ____, No ____
Fault location?Yes ____, No ____
Part removal?Yes ____, No ____
Part repair?Yes ____, No ____
Part replacement?Yes ____, No ____
System checkout?Yes ____, No ____
Calibrations?Yes ____, No ____

If yes, describe _____

20. What type of maintenance technicians do you consider necessary to have aboard to satisfactorily keep the equipment "on the line?"

21. Do any bulkheads, brackets, or other units interfere with the operation of the system?

No ____ Yes ____ If yes, describe _____

22. Are the equipment components mounted so that you can gain access to them without danger from electrical charge, heat, moving parts, chemical contamination, radiation, or other hazards?

No ____ Yes ____ If no, describe _____

23. For the manuals that were available, please rate:

a. Adequacy of equipment description?

Excellent -- Sat -- Unsat -- None -- N/A

Comments _____

b. Usefulness of troubleshooting details/schematics:

Outstanding - Excellent - Good - Fair - Poor - Unsat - N/A

c. Usefulness of maintenance procedures?

Outstanding - Excellent - Good - Fair - Poor - Unsat - N/A

Comments _____

d. Quantity of the illustrations?

Outstanding - Excellent - Good - Fair - Poor - Unsat - N/A

Comments _____

e. Quality of illustrations?

Outstanding - Excellent - Good - Fair - Poor - Unsat - N/A

Comments _____

f. Usefulness of parts lists for ordering spares?

Outstanding - Excellent - Good - Fair - Poor - Unsat - N/A

Comments _____

g. Usefulness of troubleshooting schematics?

Outstanding - Excellent - Good - Fair - Poor - Unsat - N/A

Comments _____

h. Would you recommend additions to the technical manual to improve maintenance for the equipment?

No _____ Yes _____ If yes, name them _____

i. Usefulness of the corrective maintenance section?

Outstanding - Excellent - Good - Fair - Poor - Unsat - N/A

Comments _____

j. Description of new terms, acronyms, and abbreviations adequate and clearly defined?

Outstanding - Excellent - Good - Fair - Poor - Unsat - N/A

Comments _____

APPENDIX B

PROJECT PERSONNEL

1. ASSIGNED PERSONNEL - U.S. COAST GUARD

USCGC BOLLARD (WYTL 65614)

BMC Carlesco
BMC Cassin
BM1 Boardman
MK1 Vargas
MK2 Guilford
SN Weaver
SN LeClair
SN Smith

55' Aids to Navigation Boat (ANB 55103)

ANT Bristol, RI
BMC A.D. Skaggs
QM2 J.M. Swanson
MK3 D.W. Marshall
SN J.T. Bushoven

USCG Group Woods Hole (Reserve)

<u>Crew A</u>	<u>Crew B</u>
PS1 J. Smith	BMC R. Hopkins
MK1 J. O'Neal	BMC C. Morton
QM2 K. Messner	MKC W. Collette
BM2 D. Pratt	MK2 L. O'Rourke
MK3 S. McNamarra	

USCGC BITTERSWEET (WLB 389)

Commanding Officer: LCDR W. Kline
Officers and Crew

USCG Research and Development Center

Dr. L. Alexander
Dr. S. Allen
CWO3 A. Averin
ET3 B. Barney
Mr. R.D. Crowell
LT C.A. Gilbert
LT C.A. Kohler
Mr. L. Luft
ET1 R. Miller
Mr. D.J. Pietraszewski
Mr. J.W. Spalding
LCDR C.S. Viehweg
Mr. R.T. Walker

2. ASSIGNED PERSONNEL - U.S. NAVY

USS AFFRAY (MSO 511)

QMC(SW) G. Smith
STG2(SW) S.D. Brodie
ET3 D.A. Detwiler
OS2 W. Morrison

USS EXPLOIT (MSO 440)

BM3 J.M. Jarama
BM2(SW) T.L. Mellen
STG2 J.A. Richardson
ET2 J.J. Kerr
ET3 C.A. Troup
ST3 J. Garcia

Commander, Naval Surface Group FOUR

LT W.J. Lane
LT C.L. Wilson
LT L.R. Carter
LT D.A. Newton

NR MARDEZSECONE BOSTON

CDR Carl Borowski
LT Mary Fisk

3. CONTRACTOR PERSONNEL

Meridian Ocean Systems

Douglas Smith
Philip Howells
Andrew Pearce

APPENDIX C

Ferranti ORE TRACKPOINT II Hydrophone Swing-Arm

The hydrophone swing-arm assembly was based on the manufacturer's (Ferranti-ORE) suggested design (Figure 2-1). Relatively few modifications were required in adapting the assembly to any of the three vessels. The manufacturer provided a stainless steel bracket for aligning and attaching the hydrophone to the swing pole. The balance of materials were procured locally through a mechanical contractor.

The main pole was fabricated from Schedule 40, 3" black iron pipe of adequate length to extend 6' below the ship's keel. Standard 10' sections of pipe were joined with extra heavy companion flanges and stainless steel hardware. A length of angle iron was welded to both the leading and trailing edges of the pole. This acted to reduce the drag on the pole while underway and to stiffen the pipe sections. A "L" section was fabricated and then welded to the upper end of the swing-pole to form the pivot arm. Onboard the 180' WLB, a 6' length of pipe was welded to the ship's rail, aft of the buoy port on the port side and formed the sleeve for the pivot arm. The sleeve was further reinforced by means of a leg welded to the inboard end of the sleeve and the buoy deck. A pipe support was welded to the hull such that the pole would lie against it when deployed. The pole was stabilized with fore and aft tension cables. Once the assembly was complete the hydrophone was attached to the lower end of the pole using the bracket provided by the manufacturer.

Attention to the alignment of all pieces during fabrication is critical in order to insure that the hydrophone is properly oriented when deployed (Figure 2-2). If the fore and aft axis of the hydrophone is not parallel with the longitudinal axis of the vessel, errors in the computed solution for the towfish position will occur.

For the 65' WYTL and the 55' ANB, the assembly was fabricated and installed by personnel from the USCG Research and Development Center with assistance from USCG Station New London and Ship's force. For the 180' WLB, once the material and plans were provided, Ship's force fabricated and installed the assembly in less than 1.5 days.

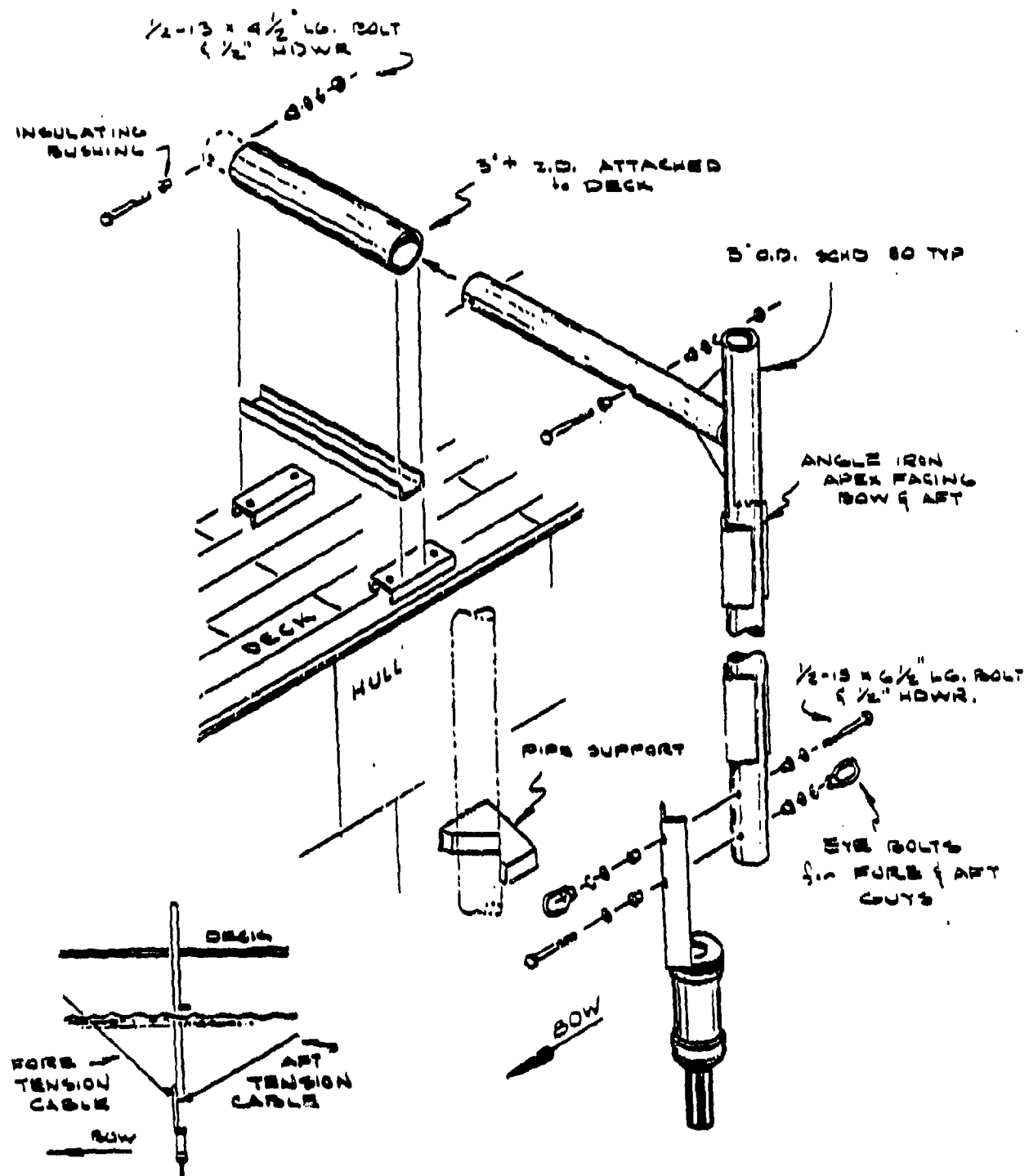


figure : 2-1

SUGGESTED HYDROPHONE MOUNTING
for SLOW-SPEED OPERATION

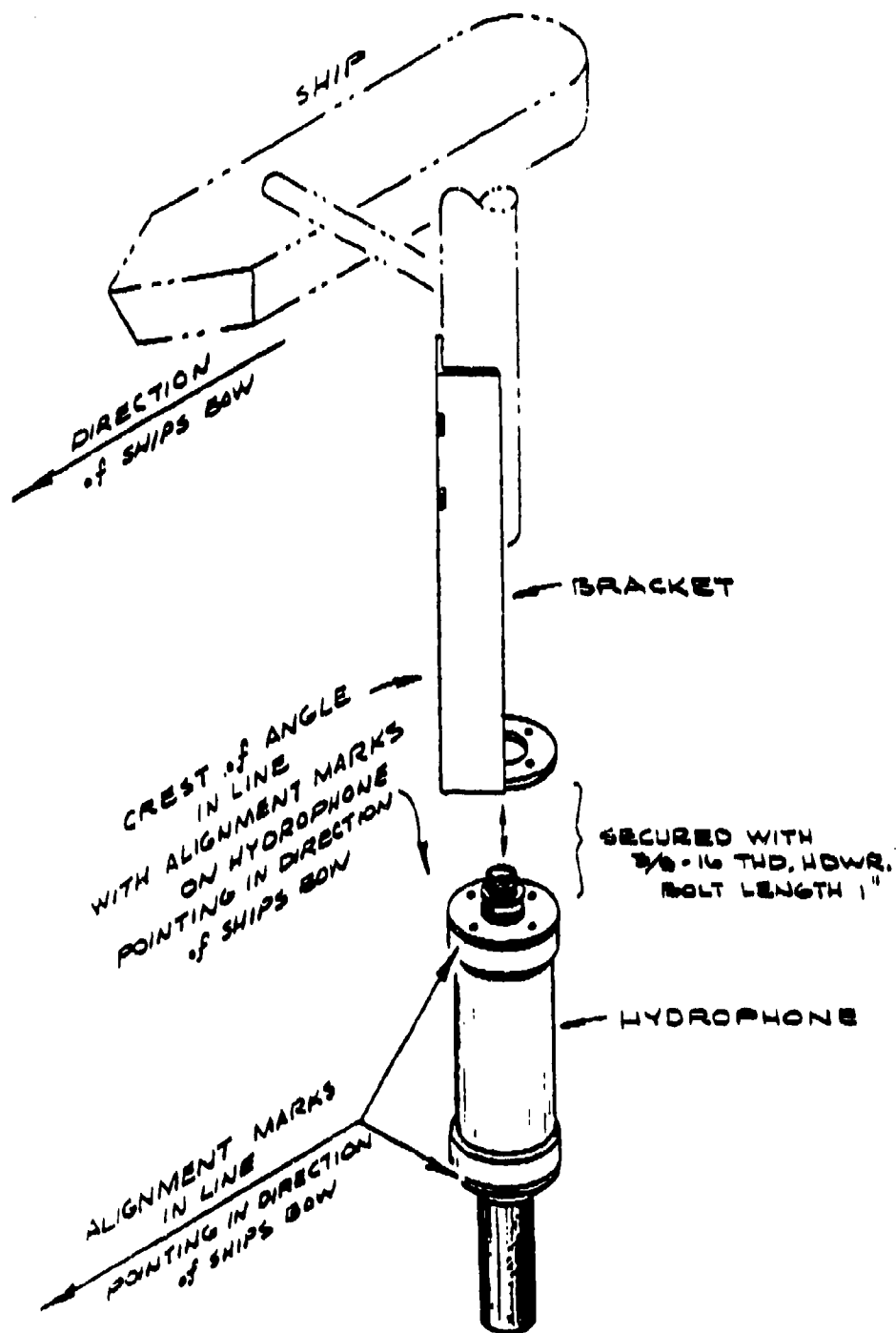


Figure 2-2

The main disadvantage of the swing-arm assembly design is that the pipe support protrudes from the ship's hull and can interfere with other ship operations. The alternative solution is to fabricate an access tube and gate valve assembly which is then permanently mounted in the bilge area. A smaller hydrophone designed specifically for this application can then be housed in a tube attached to the inboard side of the gate valve which penetrates the hull. To deploy the hydrophone, the gate valve is opened and the hydrophone is lowered until it is below the keel. The hydrophone may then be lowered by the use of block and tackle or by a small electric motor. With this arrangement, the Vertical Reference Unit which is normally housed in the larger hydrophone, comes in a small box and must be attached to a bulkhead. Orientation of this unit relative to the hydrophone and the earth's local vertical axis is critical.